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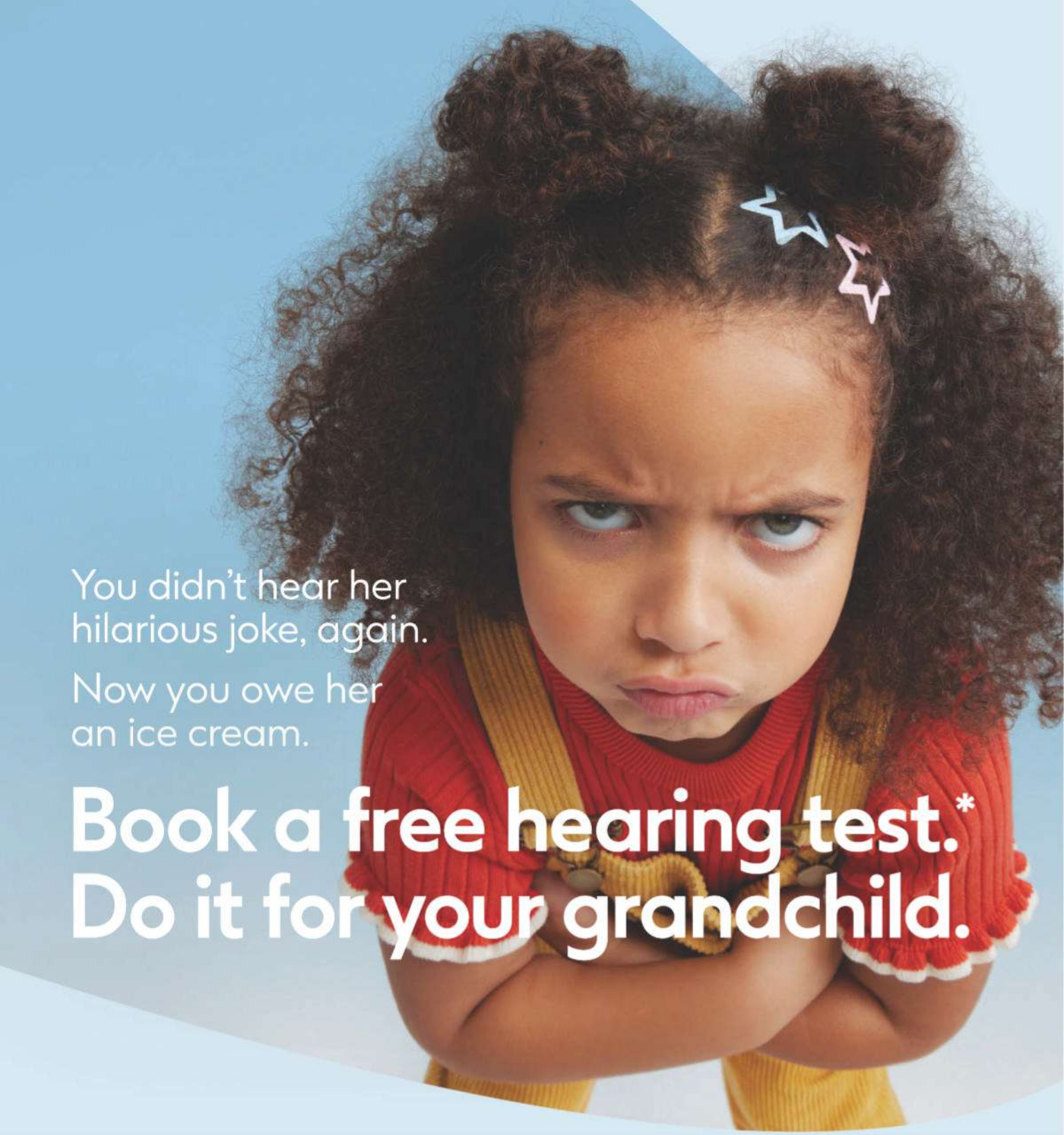

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Cover image: Simon Prades

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Online event

Detecting black holes

Despite the mysterious nature of black holes, evidence suggests they are abundant in our universe. Join theoretical physicist Delilah Gates as she reveals how black holes can be observed and studied using wave-related phenomena, including frequency shifting of light and space-time ripples. This free, subscriber-only online event takes place on 10 June at 6pm BST/1pm EDT.

newscientist.com/events

Tour

Mysteries of the universe, Cheshire, England

Spend a weekend with some of the brightest minds in science, as you explore the mysteries of the universe with an exciting programme that includes an excursion to UNESCO World Heritage Site Jodrell Bank to see the iconic Lovell Telescope. This three-day tour starts on 27 June and costs £1099.

newscientist.com/tours

Podcast

The world, the universe and us

In this AI special, the team is joined by science writer Adam Becker and computational linguist Emily Bender to learn just how large language models like ChatGPT work. They ask if artificial general intelligence is even possible, or desirable. Plus, they discuss the money that is being spent on AI development, and wonder whether it is a bubble waiting to burst.

newscientist.com/nspod

TONY WRIGHT/EARTHSCAPES/ALAMY

Eye on the sky Visit the Jodrell Bank Observatory in Cheshire, UK

Smell training Our reporters put their noses to the test

Video

Can training your sense of smell help reverse cognitive decline?

A declining ability to detect scents is linked to conditions including Alzheimer's. Restoring our nasal know-how might not only reduce cognitive decline – it could even reverse it. Our reporters put the latest scent training kits to the test and explore the research behind our most neglected sense.

youtube.com/newscientist

Newsletter

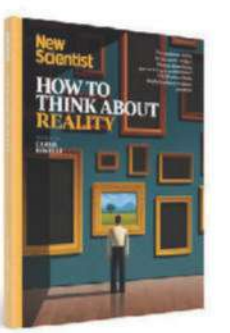
Lost in Space-Time

For more than a century, astronomers have been debating the Hubble constant, an attempt to measure the expansion rate of the universe. In this issue, science writer Jim Baggott explores the history of the "Hubble wars" and asks whether they might be about to come to an end.

newscientist.com/lost-in-space-time

Podcast

"Before ChatGPT, AI felt like something quite remote"



How to think...

In the second issue of our new *How To Think About* series, we are diving into the mind-bending concept of reality, with the world's best scientists and philosophers as our guides. Together, we will explore groundbreaking ideas that bring us closer than ever to unravelling the true nature of the universe.

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Are we doing enough?

Avoiding a mass extinction sounds ambitious – but some argue it is too easy

COULD you run for 100 hours this year? How about just doing a little more than 15 minutes each day? In fact, these goals are essentially equivalent, but one certainly sounds more ambitious than the other.

The correct framing, then, is important when setting a goal. Take averting a sixth mass extinction. It definitely sounds hard. Mass extinctions are devastating events – there is no precise definition, but these are broadly understood as leading to the loss of about 75 per cent of all species on Earth over the course of at least several thousand years. And yet, some people argue that stopping one is easy.

That is because, while humanity has certainly caused catastrophic biodiversity loss, even if extinction rates remain as high as they are today, it would take us centuries to wipe out three-quarters of species.

According to John Wiens at the University of Arizona (see page 32) and others, avoiding a textbook extinction could still be devastating. "We could lose half the species on the planet over the next 3000 years and still say,

"We could lose half of all species over the next 3000 years and still say, 'Yeah, we did it!'"

'Yeah, we did it! We prevented the sixth mass extinction,'" he says.

Instead, he argues that we should aim to prevent human-induced extinction from hitting 0.2 per cent of species – a far cry from the 75 per cent needed to qualify for a mass extinction, and the equivalent of boosting that annual 100-hour running target to more than 100 hours a day, which certainly would be a challenge.

Wiens's target is far from impossible, however – merely very difficult – and his questioning of the framing of the "sixth mass extinction" is an attempt to focus on conserving vulnerable species today, rather than centuries from now.

But the approach isn't without controversy; his questioning of the definition of mass extinction could be seen by some to undermine the argument that we are facing one now. Should we, then, just stick with the label? Doing so would arguably be the easy choice. But by highlighting their concerns, Wiens and colleagues have chosen the harder – and perhaps better – option. ▮

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© 2025 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Warners Midlands Plc

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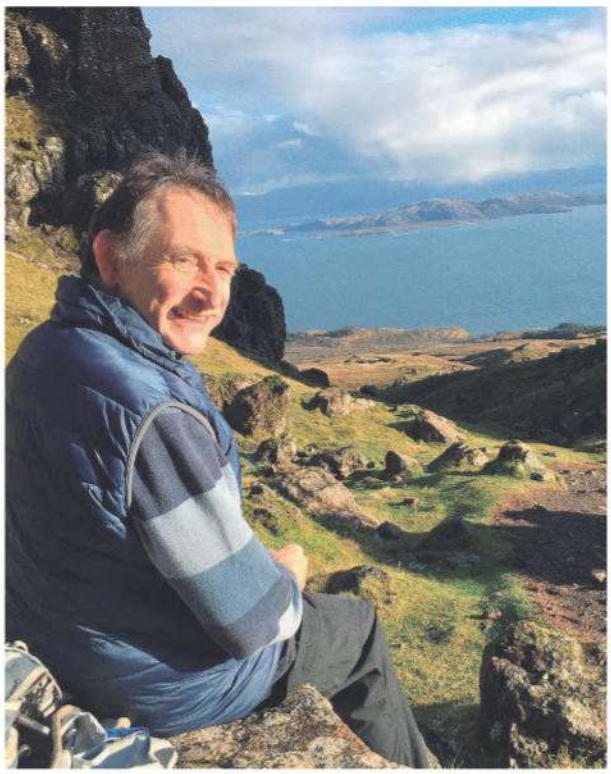
People can be a happy place.

Jo's four children are his. His world is never bigger than with them. Out on a hike. Everyone together. It's when Perthshire is at its most beautiful.

But his favourite bit? When the walk is finally over and the whole family sits down for a proper cup of tea and ever-so-slightly overdone fruit cake.

It's what made his late wife, Sue, happiest. The brood of kids all around her. Stomachs and hearts full. And it's the part he now cherishes most.

That's why he left a gift to Cancer Research UK in his Will.



So more famillies can have more time together.

For **Daniel**, it's been twelve more years with his loved ones - and counting. His Hodgkin Lymphoma diagnosis at just twenty-three was a huge shock. He felt lost, but never alone. His boyfriend Adam holding his hand every step of the way.

After four rounds of chemotherapy and two weeks of radiotherapy, which CRUK pioneered, he was given the all clear.

In 2023, he and Adam celebrate their first anniversary as husband and hubby. Cherishing every anniversary since.

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Roll the dice
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Space

A magnifying glass to the early universe

THE bright light at the centre of this image is galaxy cluster Abell S1063, which lies 4.5 billion light years from Earth. Photographed by the James Webb Space Telescope, this cluster is so massive that light from galaxies behind bends around it, creating the surrounding warped red arcs. This gravitational lensing lets the cluster act as a magnifying glass through which we can peer into the early days of the universe.

ESA/WEBB, NASA & CSA, H. ATEK, M. ZAMANI (ESA/WEBB)

Quantum physics

Does free will actually exist?

Quantum experiments could soon reveal if we have only partial free will, with implications for everything from religion to quantum computers, finds **Karmela Padavic-Callaghan**

IT HAS long been debated whether quantum physics places limits on the extent to which we have free will. This stems from the way different physicists interpret the mathematics of quantum theory, but now researchers say they have come up with a way to test the idea and finally settle the matter.

"Everyone has their own opinion on what is going on behind quantum theory. But it shouldn't matter what we think. The only thing that matters is what we can prove through mathematics and through experiments. And this is what we are doing," says Adán Cabello at the University of Seville in Spain.

One of the strangest properties of quantum physics is "non-locality". Here, if quantum objects are "entangled", they can unexpectedly maintain coordinated behaviours across extremely large distances.

The mechanisms that underlie this coordination aren't yet understood, but the debates about them go back decades – and have involved ideas such as foregoing free will.

A pivotal moment in studying non-locality came in 1964, when the physicist John Stewart Bell came up with a way of measuring it.

Bell developed a way for two hypothetical experimenters, Alice and Bob, to each study one of two entangled particles and determine the extent to which they are correlated, even over large distances.

Plugging their data into Bell's "inequality" equation reveals whether the particles are correlated in a non-local way that exists only in quantum physics.

Decades of experiments, including those awarded the 2022 Nobel prize in physics, have consistently found that Bell's inequality is violated and that particles do maintain non-local quantum properties.

But there is still room to ask why, which is where the work of Cabello and his colleagues – Ravishankar Ramanathan and Carlos Vieira, both at the University of Hong Kong – comes in.

The researchers focused on three assumptions baked into Bell's scenario. These are known as measurement independence, parameter independence and outcome independence.

"The only thing that matters is what we can prove through mathematics and through experiments"

All three ensure that there aren't any unaccounted-for correlations or coordination attempts between Alice's experiment and Bob's – for instance, that their measurement devices are secretly connected or somehow communicating with each other, which would violate the assumption of parameter independence, or that the outcomes of all measurements are somehow predetermined, which would violate the assumption of outcome independence.

The assumption of measurement independence, however, is particularly significant because it can be linked to the notion that each experimenter has free will throughout the experiment.

If there were a hidden law that made Alice act in a certain way whenever Bob acted in another, then the correlations in the data could be chalked up to this law rather than non-local correlations.

The oddness of non-locality would be avoided, but at the cost of Alice and Bob not being truly free to make choices regarding how they use their measurement devices during the experiment.

Some past experiments have already focused on the role of human choice in Bell tests – for instance, in an experiment where Alice and Bob's measurement settings were determined not by an individual, but by the collective actions of 100,000 people playing an online video game.

Big repercussions

But now, Cabello and his colleagues are taking this a step further and considering whether some of the independence assumptions can be relaxed. For example, could Alice and Bob have only "partial" free will? In other words, could their actions, on some occasions, be predetermined?

The situation would be analogous to being able to choose whatever you want for breakfast on most days, but occasionally the laws of physics intervene to force you to eat cereal.

It sounds strange, but the researchers have come up with several new equations, similar to Bell's inequality, that would let experimenters test this idea (*Nature Communications*, doi.org/pp3n).

Nicolas Gisin at the University of Geneva in Switzerland says that the work could help eliminate some of the competing ideas for why quantum theory is non-local. "The experimental violation of Bell's inequality is an established fact. This is done now," he says. "But you always have assumptions if you want to have a theorem."

Cabello says that experimentally eliminating the possibility of partial free will would have implications for the philosophy of religion. "Many religions resolve the conflict between the concept of an

WIRESTOCK, INC./ALAMY

Which way to go? The decision might already have been made for you

omniscient God and God's commandment not to commit sin by assuming human beings have partial free will," he says. But if partial free will isn't possible, neither is this resolution.

There could also be repercussions for some of the more extreme interpretations of quantum theory. These include superdeterminism, which claims that, despite appearances to the contrary, still-hidden laws of physics dictate everything that happens, including violations of Bell's inequality.

In the superdeterminist view, Bell's protocol doesn't identify non-locality, but rather reflects the fact that much about the physical world is predetermined – a view that naturally raises the possibility that the laws of physics are at odds with unlimited free will.

"We've either got to face the fact that the world is indeterministic, or that the world is deterministic and we have to explain Bell's theorem," says Tim Palmer at the University of Oxford, who studies superdeterminism and thinks the new work could help us to do the latter.

"Within my view, we have to explain Bell's theorem within the deterministic world. I think it can be done by violating this measurement independence assumption," he adds.

Cabello and his colleagues are now developing experiments to take their new equations from theory to a real test of free will. Ramanathan says quantum computers may be helpful here because the question of relaxing some independence assumptions, or some parts of the computer influencing some of its other parts, can't be avoided because of their compact design. "The priority is to do the experiments," says Cabello. ▮

Evolution

Fossils show puzzling lack of adaptation to climate change

Michael Le Page

CHRISSTOCKPHOTOGRAPHY/ALAMY

Sabre-toothed cats were slow to evolve in the face of cooling

STUDIES of tens of thousands of fossils from the La Brea tar pits in California have found no clear evidence of any of the species evolving in response to falling temperatures as ice sheets spread across the continent, or to the later warming when the glacial period ended.

"They're not fluctuating with climate change like so many biologists believe that everything must do," says Donald Prothero at California State Polytechnic University in Pomona. "They're static, despite obvious evidence of climate change at 20,000 years ago."

While Charles Darwin thought that evolution was gradual, it has become clear that it is often very rapid. There are numerous examples, from bedbugs evolving pesticide resistance to owls getting browner as snow becomes less common.

Yet fossils show that many species have remained largely unchanged over millions of years. It might be that the rapid evolution seen in living animals doesn't usually add up to big, long-term changes because it keeps reversing direction – in other words, that evolution goes nowhere fast.

The fossil record is usually too sparse to test this. But at La Brea, tens of thousands of animals

> **"They're not fluctuating with climate change like many biologists believe everything must do"**

were preserved in tar pits over a relatively short period – the past 50,000 years. More than a million fossil bones have been recovered so far.

During this time, conditions cooled until the glacial maximum around 20,000 years ago, then began to warm again. Prothero thinks animals should have evolved to cope with the much colder conditions by evolving larger bodies and relatively shorter limbs to help conserve heat, as seen in many animals living in colder regions today.

He and his colleagues have looked at fossils of 28 bird species and seven mammal species, measuring the size of adult bones and the ratio of thickness to length in limb bones (*Paleobiology*, doi.org/pp3k). The mammals include extinct wild horses, camels, sabre-toothed cats and American lions, as well as bison, cougars and lynx. The birds are mostly predators such as eagles and condors.

The average size and relative limb length does rise and fall a little over time, but there is no significant change around 20,000 years ago, Prothero told a recent meeting of the European Geosciences Union in Vienna, Austria.

In response to his findings, some biologists have pointed out that large animals such as condors and bison have huge ranges and so are less affected by local climate change, says Prothero. Smaller animals are rarer at La Brea, but the team did go back and look at three smaller birds – ravens, magpies and meadowlarks – with the same results.

He says we don't know why the expected evolutionary changes don't seem to have happened. "I still don't have a good answer for why we have stasis."

Andrew Hendry at McGill University in Canada points out that despite the large number of fossils at La Brea, they provide only very occasional snapshots rather than a detailed picture of changes over decades or centuries. "Contemporary evolution is a ton of back and forth around adaptive peaks," he says. "If you had good data for La Brea, that is precisely what you would see." ▮

Archaeology

New technique unlocks the secrets of ancient human brains

Michael Marshall

IT IS now possible to obtain proteins from preserved soft tissues like brains. The new method could reveal details of human history and prehistory, and of evolutionary history, that were previously impossible to know. That includes what animals ate, the microbes they had in their guts and even how human brain cells changed over evolutionary time.

"There are soft tissues preserved over half a billion years of Earth history," says Alexandra Morton-Hayward at the University of Oxford. Such tissues could now be mined for proteins. "The amount of biological information is just massive."

All living organisms contain a variety of proteins, molecules that play roles in everything from the beating of hearts to brain signalling. When organisms die, the proteins rot away. However, if tissue is preserved, some of them can survive.

Researchers have already used

ALEXANDRA MORTON-HAYWARD

Proteins can now be reliably recovered from centuries-old human brains

such proteins to reveal information about long-dead organisms. However, so far they have mostly used those from hard tissues.

"The vast majority of the field is bones and teeth," says Morton-Hayward. This reveals limited information, for instance what species a specimen belonged to and how closely species are related.

A handful of studies have looked at preserved skin and hair, in the form of leather and fur. However, these contain few proteins. "The biological information that skin and hair contain is really limited," says Morton-Hayward.

In contrast, internal organs such as brains and livers contain "more than 75 per cent of all human proteins", says Morton-Hayward. However, there hasn't been a reliable way to extract [the proteins] from preserved remains. "There are soft tissues in fridges and freezers all over the world," she says, but they aren't being studied.

In a 2024 paper, Morton-Hayward and her colleagues showed that human brains are

"Human brains are preserved surprisingly often within the archaeological record"

preserved surprisingly often in the archaeological record, in waterlogged graves, for example. In the wake of this, they obtained samples from preserved brains – including 456 that date back up to 300 years, all from an archaeological dig in Bristol, UK.

Her team used 10 samples from these brains, each weighing 50 milligrams, and tried a series of different methods to see which would release the most protein.

They found that urea, a chemical found in urine, successfully broke down the brain cells and released the proteins within, without damaging them. The team then broke the proteins down into smaller fragments, which could be identified using a mass spectrometer. The most successful method identified 1205 proteins (*PLoS One*, doi.org/g9mnp7).

"This would be probably one of the first, if not the first, [study] to do that," says Ragnheiður Diljá Ásmundsdóttir at the University of Copenhagen in Denmark. It "piqued my interest to see that this might be possible", she says.

While the team tested the method on brains, it should work equally well on other soft tissues such as liver or gut, says Morton-Hayward. ▮

Space

Take a look at the sun like you've never seen it before

ASTRONOMERS have revealed new processes taking place in our sun's atmosphere, thanks to exquisite new images of the star.

Dirk Schmidt at the US National Solar Observatory and his colleagues used the Goode Solar Telescope in California to produce the images.

They used a technique known as adaptive optics to remove the blur of Earth's atmosphere when observing the sun, allowing them to observe features in the corona, the star's outer atmosphere.

"You see dramatically more detail that it's unlikely anybody has seen before," says Schmidt.

Those details include streams of plasma dancing through the corona and loops of plasma known as solar prominences breaking apart and reforming.

The images also show some of our best-ever views of coronal rain, city-sized droplets of plasma that fall to the sun's surface as they cool and become denser. "They are pulled down to the sun's surface by gravity," says Schmidt.

The observations were taken in the summers of 2023 and 2024. It is hoped that some of the imagery might give us new insights into why the sun's corona is so much hotter than its surface – millions of degrees compared with thousands of degrees – a mystery that remains unresolved.

SCHMIDT ET AL./NJIT/NSO/AURA/NSF

Streams of plasma dancing through the sun's outer atmosphere

One possibility might be magnetic fields snapping together in the sun's corona. "In many images and movies we provide, you can see tangled and twisted structures and twisting motions on very small scales," says Schmidt, which might cause nanoflares that heat the corona.

Some features in the images are a mystery, including a wisp of plasma that morphed into multiple blobs.

"We are currently lacking a definitive explanation," says Schmidt. "I believe this could be something new, and it will be exciting to see how other scientists pick this up." ▮

Jonathan O'Callaghan

Will carbon dioxide removal ever make a difference? A lack of public and private support may stop the carbon dioxide removal industry from playing a significant role in meeting climate targets, finds **James Dinneen**

THE nascent carbon dioxide removal industry expects to hit a milestone this year: 1 million tonnes of planet-warming CO_2 removed from the atmosphere. That certainly is progress, but it isn't enough.

"It's not scaling up as fast as it would need to if we are going to reach multiple gigatonnes by 2050," says Robert Höglund at Marginal Carbon, a climate consultancy based in Sweden. Keeping the rise in global average temperatures below 1.5°C – or undoing any overshoot of that climate target – will require billions of tonnes of removals each year by the middle of the century.

The slow progress comes amid growing alarm in the industry that a lack of corporate climate action and a retreat from climate efforts under the Trump administration won't speed things up anytime soon. "Where is the demand going to come from and when?" says Gregory Nemet at the University of Wisconsin-Madison. "The US policy changes in the past couple months add to that concern."

The size of the problem was laid out in 2018 with the release of a special report by the Intergovernmental Panel on Climate Change (IPCC). In it, the IPCC estimated that between 100 and 1000 gigatonnes of CO_2 would have to be permanently removed from the atmosphere this century to avoid overshooting a sustained global temperature rise of 1.5°C. A more recent IPCC report called CO_2 removal "unavoidable", and estimated that between 5 and 16 gigatonnes of removals would be needed per year by mid-century, depending on how quickly we reduce emissions.

In any scenario, removing that much CO_2 is a gargantuan undertaking. "This will be the largest thing humanity has ever done," says David Ho at the University of Hawaii at Mānoa.

LEON NEAL/POOL/AFP VIA GETTY IMAGES

The world may need more carbon capture facilities like this one in Norway

The seven years since the IPCC report have given rise to a crowded slate of start-ups jostling to prove their particular technology is up to the task. The first large direct air capture facilities have come online – these blow air over chemicals to remove CO_2.

> **"It's not scaling up as fast as it would need to if we are going to reach multiple gigatonnes by 2050"**

Enhanced rock-weathering companies have spread hundreds of thousands of tonnes of rock dust on farms to convert CO_2 from the air into mineral form. Large volumes of biomass have been turned into more stable biochar or burned in power plants fitted with carbon capture systems. And other methods abound, from in the ocean to underground.

CDR.fyi, a US-based firm that tracks the industry, estimates companies have purchased 28 million tonnes of durable CO_2 removals from these start-ups to date, an amount worth about $6.5 billion. Of those, 720,000 tonnes have been reported removed. By the end of 2025, total removals are likely to crack 1 million tonnes, according to Alexander Rink at CDR.fyi, who on 20 May presented the latest data during the Carbon Unbound East Coast summit in New York.

"The [CO_2 removal] industry has been in the start-up phase for the last several years. And it's increasingly progressing into the delivery phase," says Ben Rubin at the Carbon Business Council, an industry group in Washington DC. "The million tonnes is a proof point for that."

However, at current emissions levels, removing a million tonnes is like undoing only 13 minutes out of a full year of emissions, says Ho. Testing out all the different methods might be valuable for informing future projects, but "none of it matters from a climate standpoint", he says.

Despite some large initial commitments from tech and finance firms, there has also been a persistent lack of demand from companies to buy removals. More than 90 per cent of all removals sold so far this year were purchased by just one company – Microsoft – which has pledged to become carbon negative by 2030.

A daunting task

Of the thousands of companies with climate targets tracked by the Science Based Targets Initiative (SBTi), just 0.6 per cent have purchased any amount of carbon removals, according to Rink's presentation. This number didn't budge even after SBTi released a draft of new net-zero standards the industry had hoped would encourage more companies to buy.

Some governments, including Canada and California, are set to directly purchase removals, and companies are finding less expensive ways to remove carbon or produce valuable goods at the same time. But the Trump administration's push to roll back US climate action has stalled momentum, even if some policies that support CO_2 removal look set to stay in place. "The de-emphasis on climate and net zero is not supporting private investment in the area," says Nemet.

Any slowdown adds to the billions of tonnes of CO_2 that will need to be removed in the future, making the task facing the CO_2 removal industry all the more daunting. "If we don't do that, we're screwed," says Ho. ▮

Artificial intelligence

AI weather forecasts miss extreme storms in key test

James Dinneen

TRAINING AI models on historical weather patterns can turn them into accurate forecasters – but now tests have shown they may not be able to predict extreme events that don't occur in their training data. This could be a growing issue as climate change drives more unprecedented weather.

"These models are good, but the question we have been asking is about events that are so rare and strong that these models haven't seen anything like them before," says Pedram Hassanzadeh at the University of Chicago.

Over the past few years, researchers have developed AI-powered weather models that are as accurate as conventional forecasts. Instead of calculating changes in the weather based on equations that describe the physics of the atmosphere, these deep learning models are trained to recognise statistical patterns amid historical weather and climate data.

However, an AI model's predictive ability depends on the quantity and quality of its training data. This fact led experts to worry that AI weather models will struggle to forecast events that occur infrequently – such as the extreme disasters that cause the most damage.

"Generalisation to extremes is super important, and... you'd think AI models would be poor at it," says Richard Turner at the University of Cambridge.

To test this possibility, Hassanzadeh and his colleagues retrained a leading AI weather model called FourCastNet using a dataset that excluded all instances of tropical cyclones stronger than a category 3 storm.

They found the resulting model was unable to predict the most powerful cyclones and hurricanes, events that the model trained on complete data had been able to capture (*PNAS*, doi.org/ppwv). The researchers say this shows that, unlike a conventional physics-based model, the AI model can't extrapolate stronger events from weaker ones.

NOAA/ALAMY

AI models could miss rare weather events, like Hurricane Dorian

"Climate change supercharging these extreme events can increase the likelihood that these models do not do well," says Hassanzadeh.

> **"Climate change can increase the likelihood that these models do not do well"**

The researchers tested only one of the several advanced AI weather models out there, and they looked at only tropical cyclones. But they say this same inability to extrapolate extreme "grey swan" events from past data is likely to be a problem for all models predicting all types of rare weather.

"You don't even need to invoke climate change to see that the AI models will be limited unless someone can produce a revised method that can extrapolate beyond the training dataset," says David Schultz at the University of Manchester, UK.

Encouragingly, however, when the training data included tropical cyclones in only the Pacific or Atlantic Ocean, the model was able to forecast powerful storms in both ocean basins. That means the models may be able to forecast an event that is record-breaking in one part of the world but has happened elsewhere.

The researchers say developers could link AI and physics-based models to train them on extreme events, as one way of addressing the problem.

"This is just the start of a greater assessment of the performance of AI systems and extreme weather, which is when we need them most," says Turner. ▮

Mental health

PTSD in 9/11 responders took a decade to improve

Grace Wade

ABOUT 10 per cent of 9/11 first responders with post-traumatic stress disorder (PTSD) experienced worsening symptoms 20 years on. For most others, symptoms didn't improve until nearly a decade after the event.

Frank Mann at Stony Brook University in New York state and his colleagues tracked PTSD symptoms in 12,822 emergency workers who responded to the 11 September 2001 terrorist attacks on the World Trade Center in New York City. Using a standardised questionnaire, the researchers measured PTSD symptoms on a scale of 17 to 85, with higher scores indicating greater severity. Participants could complete the survey once a year between July 2002 – a month after response efforts ended – and December 2022. On average, they did so six times over the roughly 20-year period.

PTSD symptoms remained largely stable across all participants, but for those officially diagnosed with the condition, symptoms tended to worsen during the first 10 years of the study, before gradually improving in the subsequent 10. The median time before symptoms improved – defined as a decrease of at least 10 points – was nearly nine years in those with PTSD (*Nature Mental Health*, doi.org/ppz7).

Why symptoms worsened before improving isn't clear. Patricia Resick, at Duke University in North Carolina, thinks it may have something to do with first responders not seeking treatment until after they retire.

By the 20-year mark, 76 per cent of those with PTSD saw symptoms improve. But about 10 per cent experienced worsening symptoms, highlighting the need to make treatments more widely available. ▮

Need a listening ear? UK Samaritans: 116123; US National Suicide Prevention Lifeline: 1 800 273 8255; hotlines in other countries.

Quantum computing

Start-up claims qubit breakthrough

It may soon be much easier to build error-free quantum computers – but challenges remain

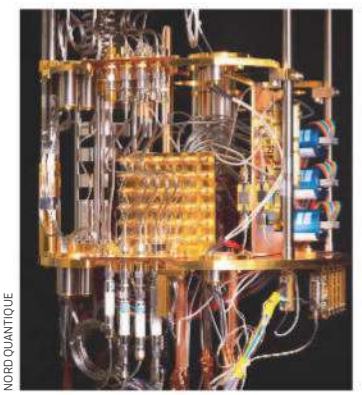
Karmela Padavic-Callaghan

A CANADIAN quantum computing start-up says its qubit will enable cheaper error-correcting quantum computers. But actually building them will be a steep challenge.

To correct its own errors, a traditional computer saves duplicates of information in multiple places, a practice called redundancy. To achieve their own version of redundancy, quantum computers would require hundreds of thousands of quantum bits, or qubits.

Julien Camirand Lemyre at Nord Quantique and his colleagues have created a qubit they say will slash that number to mere hundreds.

There are several competing versions of qubits, such as tiny superconducting circuits and extremely cold atoms. Nord Quantique's qubit is a superconducting cavity filled with microwave radiation: the particles that carry this radiation, photons, are trapped inside the cavity, where they bounce back and forth, and information can be encoded into their quantum states.



NORD QUANTIQUE

Nord Quantique is working to build error-free quantum computers

Similar qubit designs have been built before, but this is the first with "multimode encoding". This means that the researchers used several of the photon's properties at once to store information – an encoding method that makes the data more resilient to common quantum computer errors.

Victor Albert at the University of Maryland says that quantum error correction requires either more qubits – so that information can be stored in a group of connected qubits rather than a single one, protecting the system from any individual qubit's failure – or for each qubit to be "bigger" in the sense of how it stores information.

This qubit uses the second technique, storing information in a mathematical space that is effectively four-dimensional, he says.

Because of this, Nord Quantique projects that its fault-tolerant quantum computers will be up to 50 times smaller than those that use qubits made from superconducting circuits, like the most advanced ones built to date. Additionally, the company estimates machines built with its qubits will consume just a tenth as much power as these other machines.

However, Nord Quantique hasn't yet presented data on more than one qubit. Nor has it used its new qubit in a computation, other than to verify that it does in fact support multimode encoding.

"It is too early to tell whether this approach towards fault-tolerant computation... is intrinsically more advantageous than some of the other approaches pursued," says Barbara Terhal at the Delft University of Technology in the Netherlands.

> **"It is too early to tell whether this approach is more advantageous than others"**

Lemyre says he and his team are working on building more qubits and improving their current design. They expect to build a practical quantum computer with more than 100 of their error-resilient qubits by 2029. ▮

Archaeology

China's other great walls had a very different purpose

LONG before the Great Wall of China was constructed, other monumental walls were built across the Eurasian steppes – but they weren't designed to defend against Mongol armies. Recent excavations reveal that they were erected to control movement of people or demonstrate power.

Unlike the Great Wall, which is – as the name implies – made up of large walls, this earlier system is a network of trenches, walls and enclosures stretching approximately 4000 kilometres across more northerly regions in China, Mongolia and Russia.

It was built between the 10th and 12th centuries by several dynasties, chiefly the Jin dynasty (AD 1115 to 1234).

Gideon Shelach-Lavi at the Hebrew University of Jerusalem and his colleagues had already surveyed and mapped the walls using satellite imagery and drones, but now they have studied a section running for 405 kilometres through what is now Mongolia and excavated at one of the enclosures (*Antiquity*, doi.org/ppv9).

The structures were comprised a ditch about 1 metre deep and 3 metres wide, with the earth from it piled up on one side, creating a wall of compressed soil that may have been a metre or two tall. Then, every few kilometres along the wall, there was a thick, square, stone enclosure, about 30 metres across.

TAL ROGOVSKI

Excavating part of the medieval wall system in Mongolia

Many historians thought they were built to stop the armies of Genghis Khan, who ruled the Mongol Empire from 1206 until 1227, says Shelach-Lavi.

The structures wouldn't have been particularly effective, though. "This was not meant to stop invading armies," says Shelach-Lavi.

Instead, he suggests it was to demonstrate that the area was under the control of the Jin dynasty.

"The idea, I think, is to channel those people to where you have those enclosures, so you can control them, you can tax them," he says. "It's a matter of controlling who is moving, and in this respect, it's not very different from what we see today." ▮

Chris Simms

Analysis Space

What if SpaceX's Starship never works?

The rocket has had a number of setbacks, but it is still the only option for many space missions, finds **Jonathan O'Callaghan**

JOE MARINO/UPI/SHUTTERSTOCK

Starship's ninth test flight launched on 27 May in Texas

ANOTHER launch, another failure? With the ninth flight of SpaceX's massive Starship rocket ending in the vehicle's loss, questions are being asked about whether Elon Musk's company can ever deliver on its promises to take astronauts to the moon and Mars.

"I expected more progress from SpaceX by now," says Laura Forczyk at space industry consultancy Astralytical. "It's frustrating from an outsider's perspective, because I'm rooting for them. So much of the space community is relying on Starship."

The latest test flight of the largest rocket ever built took place on 27 May, launching from SpaceX's Starbase site in Boca Chica, Texas. The rocket reached space as intended, but, minutes after the large lower Super Heavy booster detached from the upper Starship vehicle, communications with the booster were lost and it crashed into the Gulf of Mexico. Starship, meanwhile, disintegrated about 47 minutes into the flight after a fuel leak. The doors of the craft also failed to open and deploy mock satellites, and the vehicle spun out of control.

SpaceX has always taken an iterative approach to rocket development, seeing failure as a learning opportunity. Responding to the latest test, Musk remained positive. "Lot of good data to review," he wrote on X, the social media site he also operates.

For Starship, this approach has seen some successes, such as the Super Heavy reusable booster being impressively caught by the company's recovery system on the ground, but the company has yet to perform a fully successful flight where the upper Starship vehicle also makes it successfully back to the ground.

"The problems we're seeing are not good, but they are things we know how to address"

Ella Atkins at the University of Michigan says this is nothing to be concerned about. "SpaceX is following its normal storyline, which is fail fast, learn faster," she says. "The problems we're seeing are problems that we've seen on other rockets. They are not good, but they are things we know how to address."

And yet, another of SpaceX's rockets, the older Falcon 9, saw success much more quickly, launching actual hardware to space from its second mission in December 2010. "I think people were hoping for a similar progression with Starship," says Forczyk, although the newer vehicle is much more complex than its predecessor. SpaceX didn't respond to a request for comment from *New Scientist*.

The continued failure of Starship is holding up other space missions. The rocket is the cornerstone of NASA's plan to return to the moon with its Artemis programme, with an uncrewed test landing of the craft on the lunar surface due to take place next year, ahead of its use in the crewed Artemis III mission to the moon in 2027.

But despite the failures and delays, Starship is currently the only option for many ambitious space plans. One rival, NASA's much-derided Space Launch System rocket that has been in development since 2011, completed a successful flight on its first launch in 2022. Its next launch is expected in April 2026 for the Artemis II mission, taking astronauts on a flyby around the moon, but it may only ever launch a handful of times.

That is in marked contrast to Musk's plans for Starship. He remains bullish about the rocket's prospects, and the frequency of test flights is set to pick up rather than slow down. "Launch cadence for [the] next three flights will be faster, at approximately one every three to four weeks," he wrote on X. Whether this will mean success or failure remains to be seen. ▮

Technology

Turning walls into cameras to see around corners

James Woodford

AN ORDINARY camera could soon take photos of things that are out of sight, thanks to algorithms that interpret how light bounces off a wall.

"Normally, when light bounces off rough surfaces, like walls, it scrambles the scene into a messy blur," says Wenwen Li at the University of Science and Technology of China, Hefei. "Our goal was to 'unscramble' that blur and recover the hidden scene. Think of it like turning a rough wall into a mirror."

The method involves mapping the geometry and reflectance of the wall surface by taking many images under different lighting conditions, so the researchers could predict how each bump and groove would distort reflected light. Once they had created a digital model of the surface, the team devised equations to reconstruct a hidden image from the scrambled light pattern.

Li and her colleagues successfully demonstrated real-time imaging at 25 frames per second using an ordinary camera, like one found in a smartphone (*Optica*, doi.org/pp2m).

Claire Vallance at the University of Oxford says this approach is an improvement on previous efforts to reconstruct images of hidden objects.

A major limitation is that, so far, the technique can only reconstruct images of objects that emit their own light, such as LCD screens and smartphone displays. Most objects only reflect light from the environment, but this results in reduced imaging precision, says Li. The team hopes to address this by developing new algorithms for diverse objects.

Once the technology gets more advanced, it could have a wide range of applications, says Li. "For law enforcement, it could provide officers with the ability to safely scan dangerous areas before entering," she says. ▮

Ornithology

Ancient birds were nesting above the Arctic circle earlier than we thought

Sofia Quaglia

NEWLY discovered bone fragments from Alaska suggest birds have been breeding and nesting in the Arctic for at least 73 million years.

"Which is kind of crazy, because it's not easy to live in the Arctic and have newborn babies up there," says study author Lauren Wilson at Princeton University.

Today, about 250 species of bird have adapted to thrive at Earth's poles. Some migrate great distances and only spend the summers there, while others stay over winter too, enduring frigid temperatures for weeks on end. But very little was known about how and when these birds first got to the highest latitudes of Earth.

Wilson and her colleagues searched for traces of ancient birds in a sequence of rocks known as the Prince Creek Formation in northern Alaska, which were formed on a coastal floodplain about 73 million years ago. At that time, that part of Alaska was about 1000 to 1600 kilometres nearer the North Pole.

The team recovered chunks of ancient soil from some thin rock layers in the formation. This work was done during the winter, when temperatures were -30°C (-22°F) and home was a tent. "It's definitely the most intense field work I've ever done," says Wilson.

Back in the laboratory, they "spent hours staring" through a microscope "at grains of sediment that are smaller than 2 millimetres", says Wilson, hunting through them carefully for tiny fragments of fossil bone.

They uncovered more than 50 ancient bird fossil fragments, many of which came from chicks or even embryonic birds. The fossilised bones of such young birds have a sponge-like texture because they represent a stage when bones are growing rapidly.

While birds probably began nesting in the Arctic even earlier than 73 million years ago, the fossils are the oldest traces of this behaviour found to date. They push back the record of this in birds by 30 million years (*Science*, doi.org/pp2r).

Still, the fossils are very fragmented. They also don't show whether the birds lived there year-round or just during the warmer summers.

Wilson's team could identify three main groups of birds among the fossil fragments: extinct toothed birds similar to loons; extinct toothed birds similar to gulls; and some species that may belong to the same group as all modern birds.

The samples, though, didn't have any bones from a group of more archaic birds known as the Enantiornithines – or "opposite birds" – which dominate the fossil records from that time all over the rest of the world. Gerald Mayr at the Senckenberg Research Institute in Germany, thinks this is a "significant" finding that could suggest that the ancestors of more advanced birds could cope with harsh Arctic conditions because of some unique evolutionary traits that the ancestral birds lacked.

The ecosystem that gave rise to the Prince Creek Formation existed at a time when large non-bird dinosaurs ruled the world, and fossils suggest the ancient birds shared these Arctic ecosystems with species of tyrannosaur and horned ceratopsians. ▮

L: GABRIEL UGUETO; R: WILSON ET AL.

Illustration of the ancient Arctic (left); Baby bird bones (below)

Environment

Hurricanes aren't cooling off the ocean like they once did

DURING a hurricane, powerful winds churn and fan the ocean, leaving behind a swathe of cold water that can last for weeks and weaken subsequent storms. But in parts of the ocean, these cold wakes aren't lasting for as long as before.

Tropical cyclones and hurricanes get their energy from heat in the ocean. Hotter sea surface temperatures raise the maximum potential intensity of storms. In turn, the storms themselves cool off the ocean as they travel along their path. That can rob any subsequent storms of energy when they pass over the "cold wake" from the first storm.

Karthik Balaguru at the Pacific Northwest National Laboratory (PNNL) in Washington state and his colleagues analysed sea surface temperatures along hurricane paths in the Atlantic Ocean between 1981 and 2020 to understand how these cold wakes might be changing.

In the central Atlantic, where most hurricanes form, they found hurricanes today cool the ocean just as much as they once did, initially reducing temperatures along their path by about 0.26°C on average. But they found that, since 2001, cold wakes generally haven't lasted long enough to weaken following storms (*npj Climate and Atmospheric Science*, doi.org/pp2ky).

The researchers estimate the effect of a missing cold wake on hurricane intensity is equivalent to 9 per cent of the rise in sea-surface temperatures due to human-caused climate change since 1980. PNNL, which is operated by the US Department of Energy, did not respond to *New Scientist*'s request for comment from the researchers.

"In the future, cyclones might get stronger due to a general increase in sea surface temperature"

"We think in the future cyclones might get stronger due to a general increase in sea surface temperature," says Shuai Wang at the University of Delaware.

According to the researchers, the shortening cold wakes are likely a consequence of climate change weakening the trade winds that fan off the ocean once a storm has passed. ▮

James Dinneen

Chemistry

Recreating the origins of life

Self-replicating RNA molecules may be how life began, and could soon be achieved in the lab

Michael Le Page

THE goal of understanding how inert molecules gave rise to life is one step closer, according to researchers who have created a system of RNA molecules that can partly replicate itself.

RNA is a key molecule when it comes to the origins of life, as it can both store information like DNA and catalyse reactions like proteins. While it isn't as effective as either of these, the fact that it can do both means many researchers believe life began with RNA molecules that were capable of replicating themselves. "This was the molecule that ran biology," says James Attwater at University College London.

But creating self-replicating RNA molecules has proved difficult. RNA can form double helices like DNA and can be copied in the same way, by splitting a double helix in two and adding RNA letters to each strand to create two identical helices. The problem is that RNA double helices stick together so strongly that it is hard to keep the strands separate for long enough to allow replication.

Now, Attwater and his colleagues have found that sets of three RNA letters, called triplets, bind strongly enough to each strand to prevent this re-zipping. Three is the sweet spot, says Attwater, as longer sets are likely to introduce errors. So, in the team's system, an RNA enzyme in double-helix form is mixed with triplets.

The solution is made acidic and warmed to 80°C (176°F) to separate the helix, allowing the triplets to pair up and form the "rungs" of the double helix. The solution is then made alkaline and cooled to -7°C (19°F). As the water freezes, the remaining liquid becomes highly concentrated and the RNA enzyme becomes active and joins up the triplets, forming a new strand (*Nature Chemistry*, doi.org/ppsw).

So far, the researchers have only replicated up to 30 letters of the 180-letter-long RNA enzyme, but by improving the efficiency of the enzyme, they think that they can achieve complete replication.

"RNA is a key molecule, as it can both store information like DNA and catalyse reactions like proteins"

Attwater says this "very simple molecule system" has some intriguing properties. One is the possible link between the triplet RNA letters and the triplet code used to build proteins in cells today. "There might be a relationship between how biology used to copy its RNA and how biology uses RNA today," he says.

What's more, the team found that the triplets most likely to be involved in natural replication in the past are those that bind most strongly.

The researchers think the kind of conditions needed to drive this process could occur naturally. As it requires freshwater, it is most likely to have happened on land, perhaps in some geothermal system.

"RNA nucleotide triplets serve very specific informatic functions in translation in all cells," says Zachary Adam at the University of Wisconsin-Madison, meaning they are used to convey information. "This paper is interesting because it might point to a purely chemical role – a non-informatic function – for RNA nucleotide triplets that they could have served prior to the emergence of a living cell." ▮

Ancient humans

Humans made tools from whale bones 20,000 years ago

HUNTER-GATHERERS living along the shores of the Bay of Biscay crafted hunting tools from the bones of at least five different whale species 20,000 years ago, the oldest evidence of humans working with whale remains.

Current findings suggest that ancient humans didn't regularly use coastal resources for food and raw materials along the bay, in the north-east Atlantic Ocean, until about 19,000 years ago.

But we have limited evidence of how early humans used marine resources because the sea level has risen by around 120 metres since the Late Palaeolithic in Europe, says Jean-Marc Pétillon at the University of Toulouse-Jean Jaurès in France.

ALEXANDRE LEFEBVRE

This projectile point, which could be up to 18,000 years old, was made from grey whale bone

Pétillon and his colleagues analysed 83 previously unearthed bone tools from 26 inland caves and rock shelters in south-western France and northern Spain. These tools, which were classified as whale bone, were mostly projectile points and spear shafts used for hunting.

The team took tiny samples from each bone to analyse the chemical makeup of the collagen proteins. This revealed that only 71 tools were crafted from cetacean bones, of which 66 were definitely whales. About half of these were made from sperm whale bone, while the others were carved from fin, grey, blue and right or bowhead whale bones.

The researchers took further samples from 37 of the bone objects to determine their age. The oldest object was dated to about 19,600 to 20,200 years ago (*Nature Communications*, doi.org/ppst).

Pétillon was surprised that these tools weren't evenly distributed through time, with most being from 16,000 to 17,500 years ago. "It's a kind of fashion effect," he says. "What we have is a few objects in the beginning and then a kind of boom and stop." ▮

Sophie Berdugo

Archaeology

Medieval woman had mysteriously brutal execution

Christa Lesté-Lasserre

A WOMAN was tortured for days, killed and then put on display at the side of the river Thames in central London around 1200 years ago. The case is thought to be one of the only examples of a judicial execution of a woman in medieval England in the archaeological record.

Madeleine Mant at the University of Toronto in Canada was working on her PhD at the London Museum in 2014, where she came across thousands of remains from skeletons that had been uncovered during urban development and stored at the museum. She found one body particularly intriguing: a woman's skeleton that had been pulled from the Thames in 1991.

Scientists had already studied the remains and carbon-dated the moss, reeds and bark surrounding her, describing the case as an execution in the early Middle Ages.

Over the next decade, Mant and her colleagues re-examined the skeleton's trauma patterns with a high-powered microscope and chemically analysed her teeth.

Partially healed fractures on the woman's shoulder blades suggest she endured beating or flogging about two weeks before receiving fatal blows to her jaw and skull. Her body was left on the muddy sediment surface and surrounded by tall wooden posts for all to see (*World Archaeology*, doi.org/ppvm).

Why the woman received such treatment remains a mystery. While laws at the time allowed for capital punishment, most of the people executed were men, usually by beheading.

For Mant, the findings point towards gendered violence.

"Gender violence through time is often so private and hidden," she says. "These women lie in wait for hundreds of years to be found again, and talked about. And now we can keep them alive by studying them and speaking about them."

Health

Sex, ethnicity and education can affect how fast you age

Chris Simms

MASKOT/ALAMY

Ageing doesn't progress at the same rate for everyone

THERE has been growing recognition over recent years that ageing progresses at different rates in different people, and that factors such as stress, poor diet and smoking can accelerate it. Now, your sex, ethnicity and level of education can be added to that list.

Dan Belsky at Columbia University in New York and his colleagues analysed data on about 19,000 people from two long-running surveys: about 70 per cent of them from the Health and Retirement Study in the US and 30 per cent from the English Longitudinal Study of Ageing in the UK.

Both surveys enrol people over the age of 50, but the US one also includes some younger individuals because the spouses of those who sign up can also take part.

"We did this work to establish that the pace of ageing, not just its progress, was consequential for health span and lifespan in older people," says Belsky.

He and his colleagues followed survey participants for eight years. To see how fast people's bodies were ageing, they measured the levels of three biomarkers in the blood linked to ageing processes, known as glycated haemoglobin, C-reactive protein and cystatin C.

They also assessed the participants' blood pressure, lung capacity, waist size, walking speed, balance and grip strength.

"Groups that are at increased risk of early mortality also show signs of a faster pace of ageing"

The study revealed three main things. First, the pace of ageing accelerates as you get older. Second, the pace of ageing is faster in groups of people who tend to have a shorter lifespan – for example, men compared with women and people in the US who identify as Black or Hispanic compared with white. Third, those with a faster pace of ageing are more likely to get a chronic disease, develop a disability or die early (*Nature Aging*, doi.org/ppsr).

"What we're seeing is that groups that are at increased risk of early mortality are also showing signs of a faster pace of ageing," says Belsky.

The effects are small but significant. The difference between the pace of ageing in older men and women, or between high school graduates and college graduates, for example, corresponds to something like a 10 to 20 per cent difference in the risk of getting a new chronic disease or a 10 to 15 per cent difference in the risk of developing a disability or dementia during the study period, says Belsky.

"They have found good evidence that the pace of ageing is really important," says Lenhard Rudolph at the Leibniz Institute on Aging – Fritz Lipmann Institute in Jena, Germany. "I kind of buy into that because it's a dynamic measure and we know that pace of ageing isn't linear: it creeps slowly up and then it becomes more exponential at later ages."

Whether you get into this exponential increase in ageing at an earlier age may be a very decisive measure for how long you live, says Rudolph.

Belsky thinks the results are likely to generalise to other countries, but he says disease is affected by diet or genetic background, so there could be slightly different patterns in other parts of the world.

"Eat healthily, do cardiovascular exercise and fill your life with meaning and purpose," he says, because people with these habits tend to be biologically younger.

Analysis Health

Cord blood banking isn't living up to its promise

Storing stem cells from umbilical cord blood was seen as a way to protect babies against future diseases, but the benefits have yet to fully materialise, finds **Grace Wade**

CAST your mind back to the 2010s, when cord blood banking was all the rage. Companies pitched it almost as an insurance policy for a child's future health, preserving the stem cells in the blood for life-saving treatments just over the horizon. Yet in 2025, it has become increasingly clear that much of the promise was overblown.

"The hype was that everybody should do it because you never know if you could use it," says Andrei Rebarber at Mount Sinai West, a hospital in New York City. "But we just don't see a lot of people asking for it any more because I think there's more literature suggesting the likelihood of utilisation is exceptionally low."

Umbilical cord blood was viewed as medical waste until the 1980s, when it was discovered to contain haematopoietic stem cells, which have the ability to transform into any blood cell type. This meant it could be used to treat certain blood conditions.

Haematopoietic stem cells can also be harvested from bone marrow or circulating blood, but those in the umbilical cord offer a slight advantage: they are more immune tolerant, meaning they are less likely to attack a transplant recipient's cells. As such, cord blood transplants don't require a perfect donor match, as bone marrow does, and they carry a lower risk of relapse, says Joanne Kurtzberg at Duke University in North Carolina.

Researchers also began exploring whether cord blood could treat a wider range of conditions, including Alzheimer's disease and cerebral palsy. Given the possibilities, companies started freezing and storing cord blood privately so that families could use it in the future, when it was thought cord blood treatments would be more common. But almost none of these other potential uses have panned out, at least not yet. "A lot of [companies] say, 'Well, you never know, the science may come up with new stuff,'" says Rebarber.

APHP- COCHIN-VOISIN/PHANIE/ALAMY

A baby's umbilical cord blood contains valuable stem cells

Today, there are 17 private cord blood banks in the US and four in the UK. Upfront costs range from $99 to nearly $2000, with annual fees of up to $240 a year. But

> **"It's not a useless thing to do, and there is value in it sometimes, but I think the hype was overextended"**

despite the high price tag, few families actually benefit from banking their baby's cord blood. "The likelihood of utilising it is exceptionally low given the current technology," says Rebarber.

Cord blood stem cells are currently used to treat around 80 conditions, mostly blood cancers and disorders. However, the number of cases where privately banked cord blood is useful is even smaller. That is because many of these conditions are genetic, meaning the stored cord blood carries the same genetic variants or precancerous cells that led to illness in the first place.

The chance of someone developing a condition that could be treated with their own cord blood is estimated to be between 1 in 400 and 1 in 2500. In fact, privately banking cord blood is more useful for siblings who may develop one of these genetic conditions or cancers, says Rebarber.

Collecting adequate amounts of cord blood is also a challenge. Public cord blood banks, which store donations for anyone in need, discard samples that don't contain enough stem cells to treat an adult. But private banks don't. "The truth is, the average number they keep is enough for a child up to the age of probably 5 to 6 years, but not enough for that person as an adult," says Kurtzberg.

Cord blood is also prone to contamination due to the high levels of bacteria on the umbilical cord, says Rebarber. While public cord blood banks toss contaminated samples, private banks often don't – and some don't even inform families when samples are contaminated, says Kurtzberg.

Public vs private

To complicate matters further, a study published earlier this year suggests haematopoietic stem cell function declines over the first five years of being frozen. Anecdotally, Kurtzberg says there have been successful transplants with cord blood that was stored for 20 to 30 years. Still, the results underscore the limitations of privately banking cord blood for later use.

For all of these reasons, medical associations such as the American College of Obstetricians and Gynecologists and the American Academy of Pediatrics recommend parents donate cord blood to public banks rather than store it privately. Even so, only 112 hospitals in the US participate in public cord blood banking, largely because of the time and money it takes to do so, says Kurtzberg.

"A lot of the private banks – not all, but many of them – promised that banking your baby's cord blood would be the solution to all of these diseases that befell your baby and your family. And that's not true," says Kurtzberg. "It's not a useless thing to do, and there is value in it sometimes, but I do think the hype from 10, 20 years ago was overextended and anticipated more benefits than are going to be possible." ▮

Space

What happened to Planet Nine?

A long-hypothesised ninth planet may exist in the outer solar system – but it had a rough start

Jonathan O'Callaghan

IF THE solar system does have a Planet Nine, it was bullied by its larger siblings, exiled to the far reaches of space and only rescued from oblivion thanks to the intervention of passing stars.

Planet Nine is a hypothesised world that is five to 10 times the mass of Earth, orbiting in the outer solar system at about 400 to 800 times the Earth-sun distance. The best evidence for its existence comes from a clustering of objects orbiting far from the sun, suggesting the gravitational influence of a planetary body. But if Planet Nine is real, we aren't sure how it got there.

We know that closer-in planets form in a disc of dust and gas surrounding a star, but, like Planet Nine, some exoplanets have been seen orbiting much further from their star, up to thousands of times more remote than the Earth-sun distance, which is well outside where the disc formation process should be possible.

To investigate, André Izidoro at Rice University in Houston, Texas, and his colleagues calculated how likely it was that a world like Planet Nine could end up in such a wide orbit around our sun. They showed that, early in the solar system, the jostling of the giant planets Jupiter, Saturn, Uranus and Neptune could have resulted in Planet Nine being kicked out after initially forming closer to the sun, potentially leaving the system for good. But if this occurred early enough, in the first 3 million to 5 million years, nearby stars born in the same cluster as our sun could have prevented the planet from being completely lost by giving it repeated gravitational kicks back towards our star. Those early stars later spread out into the galaxy.

40%

The probability that a Planet Nine formed in the early solar system

"If you just eject a planet, this planet is going to become lost," says Izidoro. "But if the sun is in the cluster, sometimes you're lucky enough that you have a star approaching the sun and the encounter is just perfect, and it gives a little kick to the planet. Then the planet might have a safe orbit from that point on."

The researchers also looked at the possibility of this happening in other star systems, and found that it occurs in only 1 out of every 1000 stars, because giant planets appear to be quite rare. "The solar system is not common at all," says Izidoro, with current observations suggesting that only 10 per cent of sun-like stars have giant planets. But for our solar system, the chance of a wide-orbiting world like Planet Nine being created could have been as high as 40 per cent, provided the jostling of the planets occurred early enough in the star cluster phase (*Nature Astronomy*, doi.org/g9mf5c). "So if this planet is there, it has been there for a long, long time," says Izidoro.

Konstantin Batygin at the California Institute of Technology, who co-proposed the existence of Planet Nine in 2016, called the work an "extraordinary calculation" in how it modelled the early solar system. "This study puts the pieces together with an unprecedented level of detail," he says. "The fact that Planet Nine comes out with a probability of as much as 40 per cent is really quite remarkable." ▮

Mathematics

How to make fair dice from any shape you like

GAMERS rejoice: researchers have discovered that it is possible to transform any shape – from dragons to kittens – into a fair die.

"We started from the idea of: 'If you look at an object, can you tell its resting probabilities?'" says Keenan Crane at Carnegie Mellon University in Pittsburgh, Pennsylvania. In other words, if you roll a particular shape, what is the probability it lands in a particular orientation?

To answer this question, Crane and his colleagues developed a geometric model to compute the resting poses of any object. Rather than physically simulate the object, the model maps the corners, edges and faces of that object onto a sphere, allowing the researchers to describe how it would fall under gravity before coming to rest. For example, if a corner is the first part of the object to touch the ground, it will then fall onto an edge determined by the position of its centre of mass, and from there onto a face.

CARNEGIE MELLON UNIVERSITY

The oddly shaped dice produced and tested by the research team included armadillos and kittens

Using their model, the researchers 3D-printed seven unusual designs. These included armadillos and kittens, both designed to land in one of three orientations with equal probability, and more exotic concepts, like a single die with probabilities equivalent to rolling two standard six-sided dice.

To test each design, the team dropped them from the same height onto a hard wooden floor between 100 and 1000 times, with different people throwing the dice to limit bias, and counted how often they landed in each orientation.

The probabilities produced by these real-world tests came within 3 or 4 per cent of those predicted by their model (*ACM Transactions on Graphics*, in press).

Crane says the work isn't an "ideal solution" to the problem, but he was surprised by how momentum seemed to play only a small role in the outcome of rolling the dice. ▮

Chris Stokel-Walker

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Comment

Nobody is neurodiverse

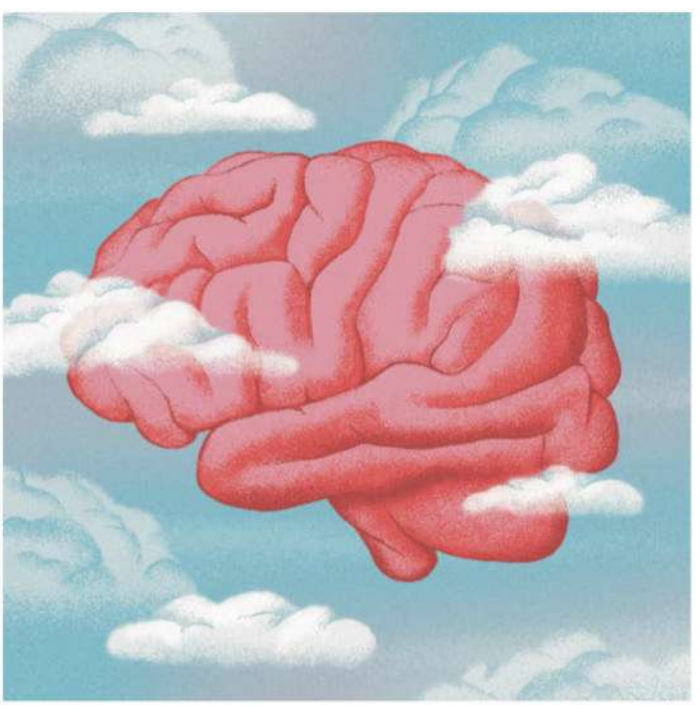
The language we use to describe conditions like ADHD matters. We need to be clearer, say **Alex Conner** and **James Brown**

LANGUAGE is how we make sense of the world: it gives form to abstract concepts and influences our perception of everything we encounter. So it isn't surprising that the language we use to describe neurodevelopmental conditions like autism and ADHD guides how people understand themselves and others, as well as how support is offered – or withheld. Confusing or imprecise language leads to misunderstanding of what neurodivergence is – and isn't.

The word neurodiversity is a good example. Increasingly, we hear "neurodiverse" used to describe individuals, as in "that child is neurodiverse". But this isn't an individual diagnosis – it is a population-level concept, similar to biodiversity. One person can't be biodiverse; likewise, no individual is neurodiverse. While identity is personal and important, semantically, no one person can represent the entire spectrum of brain differences.

The term "neurodiversity" was popularised in the 1990s, shifting the narrative away from pathology and towards the idea of natural variation in human cognition. Despite concerns that this might undermine access to medical support, it was, and is, a radical, empowering reframing. Over time, the idea of neurodivergence expanded to include ADHD and other conditions.

Neurodivergent conditions have become defined as significantly different from a hypothetical "typical" range of mental functioning – the intended meaning of "neurotypical". Unfortunately, this word began to be used as shorthand for anyone without a neurodivergent diagnosis. This created two camps: neurodivergent and neurotypical. Us and them.



ELAINE KNOX

But in reality, there is no such thing as a truly typical brain. The cognitive differences seen in ADHD aren't the same as those in autism, and even within each condition, experiences vary widely. For those without a diagnosis, it is highly improbable anyone would fall within an average range for every single cognitive function. In this sense, nobody is truly neurotypical.

More concerning is that the term neurotypical has started to be used pejoratively in some neurodivergent communities, possibly as a reaction to long-standing stigma. While this is understandable, it risks recreating the same kind of stereotyping that neurodivergent people have faced.

We advocate for clearer language. Neurodiversity should refer to the full range of human brain variation within a population. An individual whose brain functions significantly differently from the statistical norm is neurodivergent, not neurodiverse. Rather than neurotypical, we prefer more accurate alternatives like "not neurodivergent" or "someone who doesn't have ADHD".

This matters because the language we use affects more than just identity: it influences access to support, research funding, policy and public understanding. Vague or inaccurate language reinforces stereotypes and can reduce the seriousness with which conditions like ADHD are treated. Using neurodiverse to mean neurodivergent may seem like a minor issue, but it can, for instance, contribute to the idea that everyone is "a little bit ADHD", downplaying real struggles. Dismissively referring to "the neurotypicals" is just as problematic, flattening the complexity of human cognition into overly simplistic categories.

We have both seen how powerful, precise and respectful language can be. Words matter. Using accurate, inclusive and thoughtful language can foster better conversations and outcomes for everyone affected by neurodevelopmental conditions. ▮

Alex Conner and James Brown are authors of *ADHD Unpacked* and hosts of *The ADHD Adults*

Future Chronicles

Water world

In our latest glimpse into the near future, we journey to 2035, when undersea living became a reality for those affected by sea-level rise. **Rowan Hooper** tells us how it happened

Rowan Hooper is *New Scientist*'s podcast editor and the author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. Follow him on Bluesky @rowhoop.bsky.social

In Future Chronicles, he explores an imagined history of inventions and developments yet to come.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

THE Sama-Bajau are an Indigenous seaborne people from South-East Asia, sometimes called Sea Nomads. For thousands of years they lived a coastal subsistence lifestyle, foraging underwater without diving equipment and holding their breath for extreme durations. But multiple crises threatened their way of life in the early 21st century. Industrial over-fishing, pollution and coral bleaching hit their food supplies, and sea-level rise engulfed their coastal homes.

In 2035, a community of Bajau people living off the coast of Sabah, northern Borneo, raised seed funding to build a modern floating and subsea community. They worked with Deep, a manufacturer of undersea habitats, to build a network of rafts and submarine homes, creating a business model replicated by other maritime communities and populations threatened by sea-level rise. Income streams included opportunities for extreme vacations, scientific research facilities and anti-ageing clinics.

The initial habitat was a series of rafts and platforms with tunnels connecting to subsea levels. People lived in structures on the surface, but, as they got used to it, increasingly used subsea areas for eating and sleeping as well as storage. The habitats were built using a 3D-printing method called wire arc additive manufacturing, which allowed extra strength to be added in regions experiencing the most pressure.

Deeper structures were maintained both at ambient pressure – the pressure of the surrounding water – and at atmospheric pressure equivalent to the surface. In ambient modules below 20 metres deep, aquanauts breathed a specialised mixture of gases to avoid pressure sickness. Anyone leaving a deep module needed to undergo decompression when returning to normal atmospheric pressure. The advantage of ambient modules, however, was they could be fitted with moon doors – pools in the floor opening directly into the ocean. Aquanauts could swim directly out into the deep ocean, for recreation, research and farming activities.

Subsea hotels for extreme tourism became popular. In the Galapagos, tourists could stay at the Hydro-Rift Hotel, over a kilometre deep, and take trips in submersibles to hydrothermal vents, witnessing some of the most unusual lifeforms on the planet. Elsewhere, scientists used modules to study life in the deep. Seabed mapping was made easier and, over the years, researchers explored far more of the ocean than had previously been visited. Great advances were made in understanding and even communicating with whales and other deep-sea organisms.

> **"Aquanauts could swim directly out into the deep ocean, for recreation, research and farming activities"**

The Bajau were already adapted to marine life. Over thousands of years spent living on and around the sea, they had evolved large spleens, providing them with more oxygen-holding red blood cells than average humans. Some Bajau divers spent up to 5 hours per day underwater, and they were able to free-dive – without using compressed air – to 70 metres deep, holding their breath for up to 15 minutes. Once they moved to subsea habitats, some Bajau renounced the surface, spending most of their time underwater and opting for body modification and even gene editing to enhance their aquatic nature. This included intentional rupturing of the ear drum to improve diving at depth, while deep-diving Bajau used surfactants in their lungs to help them collapse at high pressure, as seen in diving marine mammals.

Some communities offered clinical treatments at depth. Earlier research had indicated that exposure to intermittent daily sessions of breathing pressurised oxygen, known as hyperbaric oxygen therapy, had benefits for a range of medical conditions and age-related diseases. People who had regular hyperbaric sessions had longer telomeres and increased clearance of old (senescent) cells, both factors known to promote longevity. Deep modules became popular with rich older people looking to prolong their lives, and provided a valuable source of income.

Most maritime communities were self-sufficient, producing all the food they needed through aquaculture of fish, molluscs and seaweed, and growing other crops on the surface. Energy was provided by a mixture of solar, wind, wave and hydrothermal power, according to location. Some specialised in tourism, some in medical facilities, some in carbon storage; growing vast amounts of seaweed, sinking it into the abyss and selling the carbon credits.

Sea life wasn't for all. But the modules empowered people who were most at risk from climate change, and provided ways for them to shape their own careers and lifestyles, even as sea-level rise wiped away their heritage. ▮

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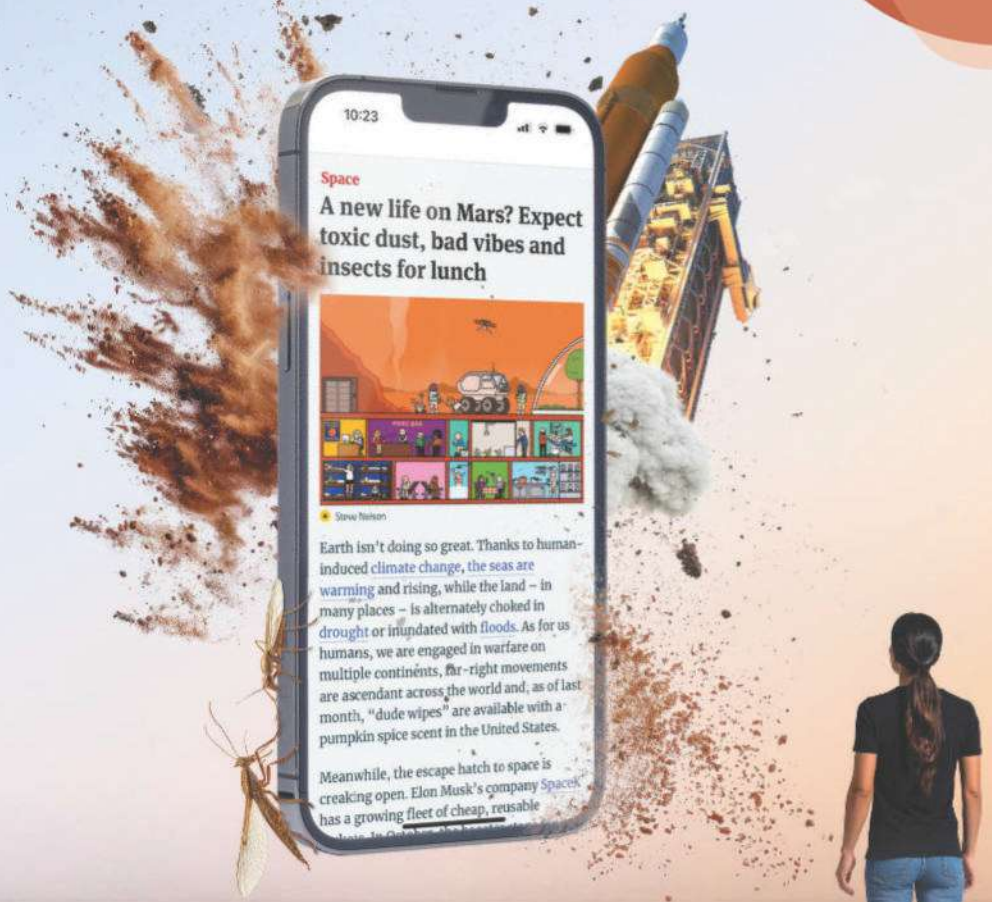
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Space
A new life on Mars? Expect toxic dust, bad vibes and insects for lunch
Steve Nelson
Earth isn't doing so great. Thanks to human-induced climate change, the seas are warming and rising, while the land – in many places – is alternately choked in drought or inundated with floods. As for us humans, we are engaged in warfare on multiple continents, far-right movements are ascendant across the world and, as of last month, "dude wipes" are available with a pumpkin spice scent in the United States.
Meanwhile, the escape hatch to space is creaking open. Elon Musk's company SpaceX has a growing fleet of cheap, reusable

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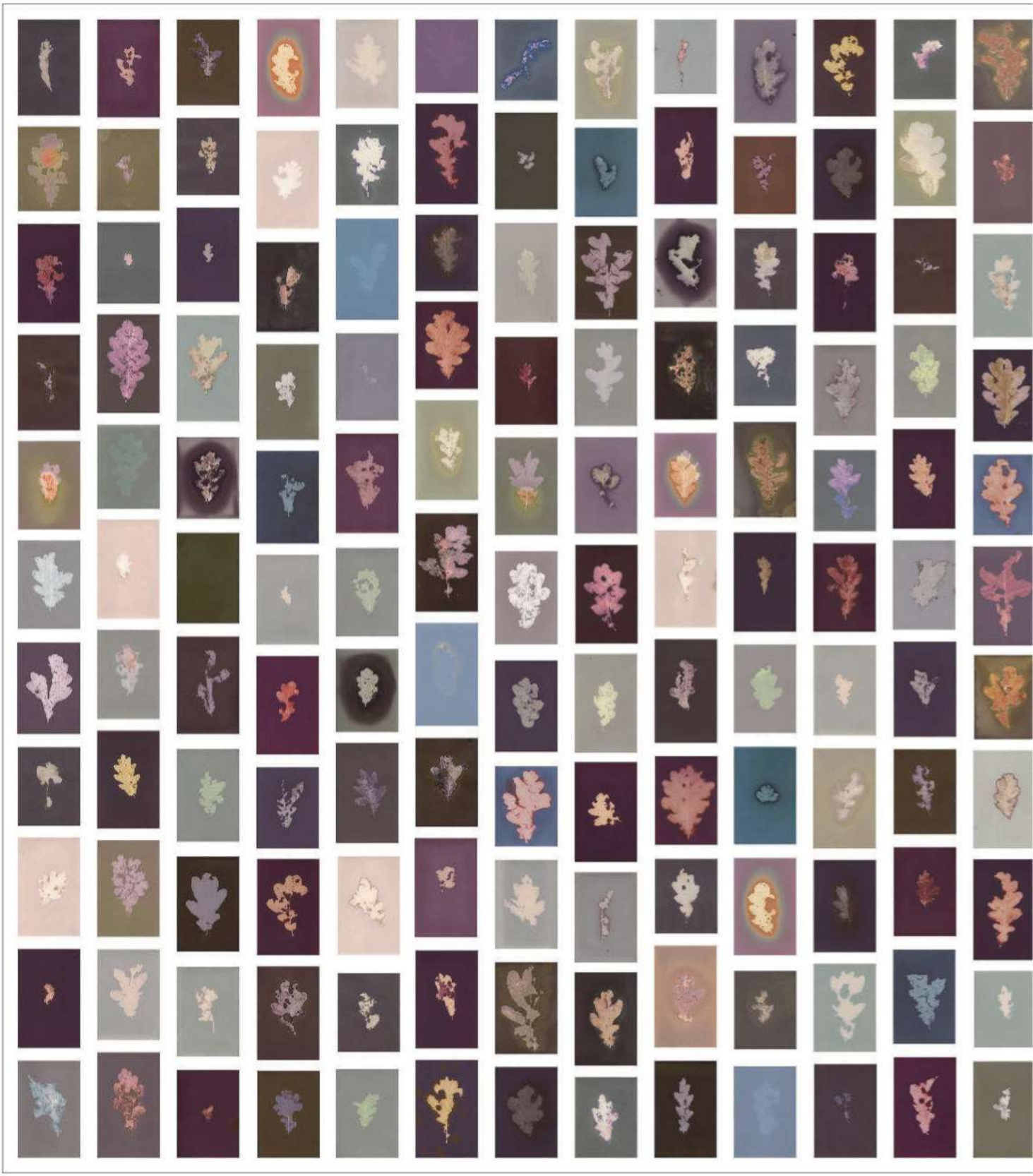


Time and light

Clare Hewitt
Impressions Gallery

AN AVERAGE mature oak tree grows hundreds of thousands of leaves each year. When those leaves fall, their nutrients return to the soil to nourish the tree that grew them, as well as other living things in the forest. "They essentially eat themselves every year," says artist Clare Hewitt. "There are these little symbiotic relationships happening between all of the forest."

Hewitt produced these oak leaf prints over five years of regular visits to a group of trees tucked within the Birmingham Institute of Forest Research, UK. In 2019, she started spending time there after reading about an epidemic of loneliness in rural areas, suspecting the trees may hold lessons about connection and sharing resources. After enough time spent with them, "you come to know them as you would know a friend," says Hewitt.

She wasn't allowed to remove anything from the ecosystem, so the forest became her studio: each fallen leaf was placed on expired photo paper, then exposed to sunlight, before being returned to the oak grove. "A lot of the photographic process is a scientific process," says Hewitt. "It's really about time and light."

The prints are part of a larger exhibition of Hewett's tree art titled *Everything in the Forest is the Forest,* at the Impressions Gallery, Bradford, UK, until 23 August , where they appear alongside other work from the grove, including a hand-crafted, biodegradable book made with mushroom-based paper and plant-based inks.

James Dinneen

Still beyond our grasp?

A new book on quantum physics is pleasingly full of cutting-edge topics. Yet it isn't the accessible work it promised to be, says **Karmela Padavic-Callaghan**

Book

Why Nobody Understands Quantum Physics

Frank Verstraete and Céline Broeckaert

Macmillan (UK, on sale; US, 10 February 2026)

QUANTUM physics isn't just complicated – after 100 years, there is an awful lot of it to understand. This makes writing an accessible yet comprehensive book about the topic a challenge in both explaining it well and finding space to describe all the parts of our world it has touched.

Frank Verstraete and Céline Broeckaert's *Why Nobody Understands Quantum Physics (And Everyone Needs to Know Something About It)* is an ambitious attempt, but the resulting 300-plus pages aren't always completely successful.

They are a married couple – she is a language scholar and a writer and he is a physics professor – who wanted to combine their academic skills to write a book that would "inspire readers to see and feel new things, and to view the world from a fresh, quantum-inspired perspective". In the preface, Broeckaert recalls struggling with mathematics in school, inviting the reader to engage with the text even if they had similar difficulties. "Quantum physics is an undeniable part of our culture," she writes, while her husband notes that it is also "far from incomprehensible".

What follows is a fast run-through of centuries of mathematics, physics and chemistry, starting in the 16th century when the foundations of empirical science were laid and ending with the present day. Their book truly has everything, from classical mechanics and the mathematics of matrices to lasers and the chemistry of combustion. Where many texts focus on one facet of quantum physics or choose to stop fairly early in its history, *Why Nobody Understands Quantum Physics* boldly moves forwards and gets to the edge of what researchers understand about quantum physics right now.

While reading, I excitedly jotted down numerous topics that I had only encountered while I was working on my PhD, yet here they were in a book for a general audience. It was wonderful to see something as technical and modern as the Hartree-Fock method or renormalization theory outside a textbook. The book ends with a brief discussion of quantum computing and quantum gravity, two truly contemporary topics that show up in my work as a reporter on the quantum beat nearly every day.

Yet even with my background as a physicist and a physics writer, I found some sections of *Why Nobody Understands Quantum Physics* more difficult to follow than the opening promised. Its chapters come in many brief sections, a rushed staccato of ideas and characters, densely filled with both jargon and tongue-in-cheek analogies or historical anecdotes.

Often, I felt the authors were choosing to be clever instead of taking the time to break down an idea and make it truly accessible.

> **"I felt the authors were choosing to be clever instead of taking time to break down an idea and make it accessible"**

While I normally love a detour into history, by the end of the book I wished that more space had been made for old-fashioned physics writing.

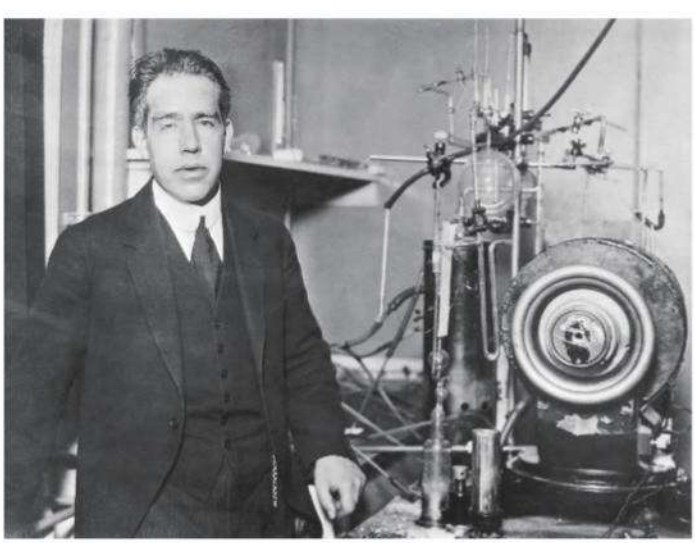
Most disappointingly, *Why Nobody Understands Quantum Physics* didn't seem to me a perfect fit for someone who is already intimidated by physics. Several sections of the book are designated as "for afficionados", thereby drawing a stark line between different kinds of readers, while I was hoping that they would encourage everyone to take on the challenge instead.

And bafflingly for a book that claims quantum physics can be understood by anyone, at one point the reader is directly told: "How does that work? Simple: by turning your intuition off and quantum logic on." Do these choices not make quantum physics feel even more mysterious?

I found aspects of the language difficult, too. Many of the historical physicists are introduced in the hyperbolic language of genius, such as when Niels Bohr is referred to as the "lord and master of quantum physics". And some linguistic flourishes also struck me as poor taste, such as referring to quantum physics having an "autistic side" and comparing equations based on which is "sexier".

The fact that this bothered me as a reader might be a matter of personal sensitivity, but it also gave me pause as a writer myself. If I used similar language in my work, I would worry about alienating some of the readers that I think Verstraete, Broeckaert and I want to reach.

Before I became a physics reporter, I taught physics, and I was often asked about quantum physics. If I recommended popular writing to a student, I worried about two things: would the physics be explained well, and what would the student infer about physicists and the culture of being a physicist. Had a student brought me this book, I wouldn't have discouraged them from reading it because it contains so much physics, but I would have definitely asked them for a debrief in office hours afterwards. ▮



Niels Bohr in his lab at the University of Copenhagen

BETTMANN ARCHIVE/GETTY IMAGES

It's not black and white

An often-playful approach to mathematical "equality" sheds light on the real-world variety, finds **Sarah Hart**

Book
Unequal
Eugenia Cheng
Profile Books (UK, on sale)
Basic Books (US, 2 September)

MIKA BAUMEISTER/UNSPLASH

Numbers allow us to focus on one aspect of a situation in detail, but can also oversimplify things

THINGS are either equal or they aren't – mathematically speaking, at least, right? Not so fast, says Eugenia Cheng in her new book, *Unequal: The maths of when things do and don't add up*. In mathematics, as in life, some things are more equal than others.

Take equations: the really interesting ones assert a sameness where there is also a difference. The equation 180 = 180 tells us nothing, but x + y + z = 180°, where x, y and z are the angles of a triangle, is a claim of another kind. And it is only true in certain circumstances – in a two-dimensional plane, yes, but not on the surface of a sphere.

Cheng's aim is to explore how we decide when things are "the same" in mathematics. Her approach is both playful and deeply serious, leavening abstract concepts with entertaining tangents on everything from knitting Möbius strips to making an iterated Battenberg cake. Neither is she afraid to discuss important political and rights-based questions around equality.

Having opened with equations, Cheng moves on to numbers, joking that the good thing about them is that they are boring. By this, she means that they reduce potentially confusing complexity to a single quantity. Numbers can be powerful tools because they let us focus on one aspect of a situation in detail.

They can also be misleading if we forget they are a simplification of reality. It would be dangerous to assume, for example, that two people who get the same score on an IQ test are equally intelligent. As Cheng says, "it's fine to forget details, but we must remember that we forgot them".

Happily, mathematics has more than numbers at its disposal. Cheng explores "local" versus "global" sameness with a discussion of manifolds – essentially, surfaces made by stitching together small, flat areas, which can end up curved on a global scale like a sphere.

"Manifold-like thinking", she argues, can be a useful lens for the real world. In mathematics, it is pointless to argue about whether a sphere and a bagel-shaped torus are "the same", because we can just say they are the same locally and different globally, then decide which is most useful for the context. Similarly, in politics, it is useful to be able to notice when one side is using a local argument (like "individual women benefit from being able to make a choice about abortion") and the other a global one (like "all abortion is murder").

Cheng really dials up the abstraction in her discussion of sameness in category theory, but do go with her on the journey. After all, some of the greatest works of art, literature and music are technically challenging, yet we still find them beautiful without knowing the intricacies of chiaroscuro, caesura or counterpoint. Cheng spends time exploring the formal definition of a category "not because I necessarily think everyone needs to understand it, but that you might like to marvel over it like a piece of abstract art". And just as with art, we all have our preference for how abstract we like it, but to find that out, it is worth going to a gallery and taking a look.

"If you think maths is all about equations, and you think equations are rigid black-and-white facts, then you probably think maths is all rigid and black-and-white," says Cheng. This book is a wonderful refutation of that misconception. Exploring the meaning of "equals" in mathematics gives us a better understanding not just of the nuance and richness of the field, but of how ideas of equality are used (and misused) in life. ▮

Sarah Hart is professor emerita of geometry and provost at Gresham College, UK. She is the author of *Once Upon a Prime*

New Scientist *recommends*

Catherine de Lange
Editor
London

The vogue for immersive shows is starting to feel stale, so when I gave in to my son's pleas to visit **Tutankhamun: The immersive exhibition** in London, it was with a sense of foreboding.

I needn't have worried. First up were replicas of items like Tutankhamun's famous death mask and sarcophagus, plus some real artefacts on loan, which excited my son. Then on to the immersive part, where, in familiar style, projections on the walls, floor and ceilings were designed to draw us

in as we ventured down the Nile and into the tomb.

Much better was the virtual reality room, where, headsets on, we embodied the young king on his journey from tomb to afterlife. But my favourite room let me "become" archaeologist Harold Carter and explore his camp in the 1920s.

It's gimmicky, sure, but also hugely imaginative and informative. While the detail was probably lost on my 6-year-old daughter, she got swept along by the exhibition, whose immersive elements really bring the subject (back) to life.

TUTANKHAMUN: THE IMMERSIVE EXHIBITION

A real space odyssey

The story of Sally Ride, the first US woman in space, makes for a moving, highly personal film, says **Davide Abbatescianni**

Film
Sally
Cristina Costantini
Disney+ (from 17 June)

NASA

Sally Ride during STS-7, NASA's seventh Space Shuttle mission, in 1983

IN 1983, Sally Ride made global headlines as the first US woman in space and the third woman after cosmonauts Valentina Tereshkova and Svetlana Savitskaya. A new documentary, *Sally,* directed by Cristina Costantini, sheds light on her extraordinary life. And it delves beyond the media spectacle to explore the complexities of her private life, including her 27-year-long relationship with Tam O'Shaughnessy, a children's science writer.

Having premiered at this year's Sundance Film Festival in January, the picture opens with a long sequence composed of archive footage, including Ride's guest appearance on *Sesame Street*, a fitting introduction to her role as an icon of empowerment.

We can sense how her determination drove her on. "It's important I don't do anything dumb," she says during her appearance on the programme – a statement that encapsulates her striving for perfection, but also the pressure she felt as a woman in highly competitive, male-dominated environments.

Ride grew up during the golden era of the US space programme. In 1976, NASA's decision to diversify its ranks opened the door for women and people from ethnic minority groups. Out of 8000 applicants for the astronaut training programme, 1500 were women – Ride, a PhD candidate in physics, among them. NASA ultimately hired 40 aspiring astronauts.

Using a skilful mix of talking heads and remarkably well-crafted staged sequences shot on film – which are so good that they are nearly indistinguishable from the extensive archival footage – the film weaves together Ride's professional ascent and personal struggles. Fellow astronauts Kathy Sullivan, Judith Resnik and Anna Fisher, along with journalist Lynn Sheer and Ride's ex-husband, Steve Hawley, offer insights into her character (some feature in that older archival material).

"In 1976, NASA's decision to diversify its ranks opened the door for women and ethnic minority groups"

For example, Fisher recalls the pressures on female astronauts to downplay their femininity, especially in terms of clothing and make-up. We also meet fellow astronaut Mike Mullane, who is initially portrayed as a hard-line sexist but who ultimately emerges as a man trapped by his own prejudices, later penning a letter expressing profound regret for his past treatment of Ride. His change of heart provides a striking reflection on the professional challenges that she faced along the way.

Costantini also manages to trace, tenderly and endearingly, Ride's lifelong bond with O'Shaughnessy, whom she met as a teenager on a sunlit tennis court when they were 13 and 12, respectively. Their relationship remained private for decades, a choice shaped both by Ride's naturally reserved personality and by the era's attitudes towards LGBT+ people.

The soundtrack, featuring hits such as *Lazy Calm* by Cocteau Twins, *Mr Blue Sky* by the Electric Light Orchestra and Neil Young's *Harvest Moon* – a song that held deep meaning for Ride and O'Shaughnessy – adds emotional depth to the narrative.

The most heartbreaking part of the story starts with Ride's pancreatic cancer diagnosis in 2011, a battle she fought privately. After delivering a speech at a conference in California, she had noticed how unwell she looked and booked a medical appointment for the following day. A medical ultrasound revealed the presence of a tumour the size of a golf ball in her abdomen.

O'Shaughnessy's testimony, in particular, conveys how their lives were upended in just 24 hours. Nevertheless, the pair managed to lead their lives to the full together until Ride's last breath. Her legacy endures, not just through her scientific achievements, but also with the Sally Ride Science non-profit organisation, which continues to inspire young women in STEM.

All in all, *Sally* is an illuminating and moving tribute to a woman who defied all expectations in both her career and her personal life. Costantini captures not only the triumphs but also the sacrifices that came with Ride's pioneering journey, ensuring that her story continues to resonate with new generations. ▮

Davide Abbatescianni is a film critic based in Rome

Editor's pick

When it comes to primal symbiosis, plants rule

17 May, p 8

From Garry Marley, Stillwater, Oklahoma, US

It was interesting to learn of a suspected archaeal host responsible for its primal symbiosis with an aerobic bacterium. The theory of endosymbiosis for eukaryotic cell origins, controversially proposed by Lynn Margulis in 1967, now has ample support with the detection of complex nucleic acids and protein synthesis within today's mitochondria and chloroplasts.

Plant cells then got a double whammy of "modular evolution" when a proto-eukaryote, already with aerobic bacteria, subsequently acquired photosynthetic bacteria via endosymbiosis. Their putative descendants – the chloroplasts – have DNA homology with modern cyanobacteria ("blue-green algae"). We must, therefore, humbly conclude that the eukaryotic plant cell has an evolutionary "one-up" on those of us composed merely of animal cells.

Pretty happy with the emotions coverage

10 May, p 30

From Pamela Manfield, The Narth, Monmouthshire, UK

I would like to share my method for addressing the emotional states of anxiety and unhappiness. Make a list of what is worrying you in one column. Then think of possible solutions and put these in the second column. Then work on how to achieve these.

It is important to physically write this on paper as, if you can't think of a solution, you cross the worry out firmly and then tell yourself to forget it as there is nothing you can do.

From Lyn Williams, Neath, UK

Your look at emotions and their impact on us was excellent. However, it is worth raising the issue of where, in my view, they come from. I believe we inherit them from our parents, and they from their parents; no one sat us down to explain how we will feel about any situation we find ourselves in – the feeling of guilt or happiness, for example.

Reservoir's plight could be a gardener's delight

17 May, p 7

From Paul Whiteley, Bittaford, Devon, UK

The image of Woodhead Reservoir in Derbyshire, UK, made me wonder about possible uses for all that newly exposed, dried-up sediment that has been slowly filling the reservoir and reducing its capacity. Much of this stuff is good-quality soil biomass that is free or mostly free of artificial fertiliser, herbicides and insecticides. I would be delighted to have some on my garden.

Quantum gravity: my take on this conundrum

17 May, p 30

From Calum Kermack, Aberdeen, UK

The energy applied by some of the world's great minds to understand quantum gravity is something to celebrate, but the lack of any real progress in over 100 years implies a gap in the thought process.

A tenet of quantum mechanics is that the wave function of a quantum particle collapses when the particle interacts with its environment. My hypothesis is that "quantum gravity" is such an environmental interaction between a quantum particle and a massive object. That interaction may be as mundane as a photon emitted by the massive object and absorbed by the particle. It causes the wave function of the particle to collapse at the point of the interaction, which will be within the volume initially occupied by the wave function. Furthermore, it can be shown that the probability function representing the location of the interaction is concentrated towards the massive object. So, the particle establishes its new wave function, now centred on the point of the collapse. The shift in the wave function's centre represents an acceleration by the particle towards the massive object, which we recognise as gravity.

Are microplastics making us blasé about threats?

10 May, p 38

From Fred White, Nottingham, UK

You report that ingestion of microplastics by mice changes their behaviour in the face of a deadly corn snake. After being given food contaminated with plastic, they failed to treat the snake as a threat. Would it be too cynical to speculate that the lack of concern over the past 40 years by humans in the face of obvious climate and ecological collapse may be due to exposure to plastics?

Extracting buried hydrogen isn't green

17 May, p 14

From Sam Edge, Ringwood, Hampshire, UK

The possibility of geologic hydrogen reserves in mountain ranges is very interesting. But Frank Zwaan saying that these or any other fossil hydrogen sources are "like a free green energy source" is naive at best. Drilling for hydrogen is neither renewable nor without substantial operational and environmental cost.

Fossil hydrogen would be better than fossil petrochemicals to use as fuel where other stored energy isn't practical, such as for aviation. However, it would be much more sustainable to generate hydrogen from clean electricity and water.

Love the idea of seeing through another's eyes

10 May, p 22

From Hilda Beaumont, Brighton, UK

Rowan Hooper's Future Chronicles instalment "Through their eyes" reminded me of the 1967 novel *Night Walk* by the Irish science fiction writer Bob Shaw. In this tale, the blind hero designs a device in the form of a pair of spectacles that transmit the signals in the optic nerves of nearby animals into his brain so that he can literally see through their eyes.

When a Dyson sphere goes supernova

17 May, p 10

From Matthew Stevens, Sydney, Australia

A solid Dyson sphere built around a star to capture all its power would be unstable, just like one made of many satellites. Even a rigid sphere with its star perfectly centred would experience gradual drift, necessitating occasional corrections, which might be visible as bursts of radiation. Without such correction, it would eventually intersect with its star, to end with a bang.

A big number to match string theory

22 March, p 30

From Matt Lee, Richmond, Virginia, US

Jon Cartwright points out "that string theory was so flexible it could describe a truly vast array of fantastical universes. Something like 10^{500} in fact – a number so huge it belied any physical comparison". I recommend taking a look at protein folding, in which there are reportedly 10^{500} potential folding possibilities. ▮

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NewScientist

Emerging Technologies Summit

New Scientist hosted a diverse and knowledgeable group of scientists, policy makers and businesspeople in London last month to talk about the world's most exciting innovations

"It may sound like science fiction," said Jacques Carolan at the UK's Advanced Research and Invention Agency, but lab-grown, stem-cell derived neurons that are implanted into healthy brains to help treat Parkinson's disease are now very much within our grasp. This was just one of many impressive developments mentioned at New Scientist's Emerging Technologies Summit in central London last month.

From synthetic plants that are more resilient to climate change to gene therapies that could treat Alzheimer's, Pippy James at ARIA spoke about the breadth of projects that she hopes ARIA might succeed with, floating even the most far-out ideas: "What if we could plant a seed that could grow into a house that a human could live in," said James. "Why couldn't we do that?"

Not science fiction, but reality, was one of the day's recurring themes. David Elizondo at De Montfort University, UK, talked through a new AI tool he and his colleagues had developed that could quickly and accurately assess whether bananas were fit for sale in supermarkets. In a real-world trial in Costa Rica, they found it cut down on waste by up to 10 per cent.

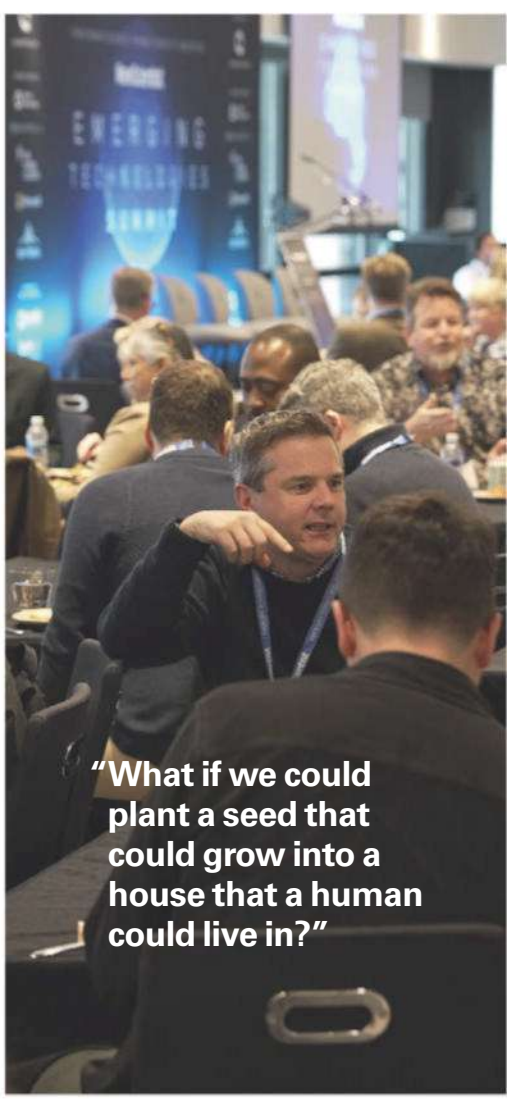
AI was, predictably, at the heart of the day's talks and panel discussions, from bananas to banking, as Rohit Dhawan at Lloyds Banking Group demonstrated with his vision for a team of AI agents that could soon help customers manage their finances or even be approved for mortgages or loans.

But speakers urged caution, too, at falling for false narratives like an AI race or artificial general intelligence (AGI), a hotly debated term that refers to AIs that are smarter and more generally intelligent than humans. "When people are talking about ridiculous things such as an AI race, what is that? It actually sits in with this notion of artificial general intelligence, that we're racing to create AGI, it's total absurdity," Neil Lawrence at the University of Cambridge told the audience in a fireside chat. Instead, businesses should be focusing on "the customer, or if you're in government, thinking about the citizen," said Lawrence.

Though AI took much of the limelight, the maturity and rapid progress in many other technologies was also front and centre. In a rare agreement between government and businesses, all three panellists from the UK Space Agency, the European Space Agency and space launch company Skyrora agreed that we were in a "golden age" for space data.

Quantum scientists and quantum computing business leaders felt similar about their industry, with progress in the last 18 months showing real scientific evidence of error correction, one of the key technologies that can unlock fully functioning quantum computers, Peter Knight, who helps lead the UK's quantum strategy, told the audience.

While it was worth not getting carried in hype cycles, it would also do us well not to constrain ourselves with what we can't do or deem impossible, said Knight. "These are three quotes from Lord Kelvin: 'I can say flatly that heavier than air machines are impossible.'; 'X-rays will prove to be a hoax.'; 'Radio has no future.'," said Knight. "We should avoid hype, but let's not close our eyes to the transformative nature of what we're trying to do."



Left: *New Scientist* editor Catherine de Lange gives the opening address

Below: The space panel discussion, hosted by *New Scientist*'s Alex Wilkins

Below, clockwise from top left:

Neil Lawrence,
University of Cambridge

Pippy James,
ARIA

Rohit Dhawan,
Lloyds Banking Group

Peter Knight,
Imperial College London

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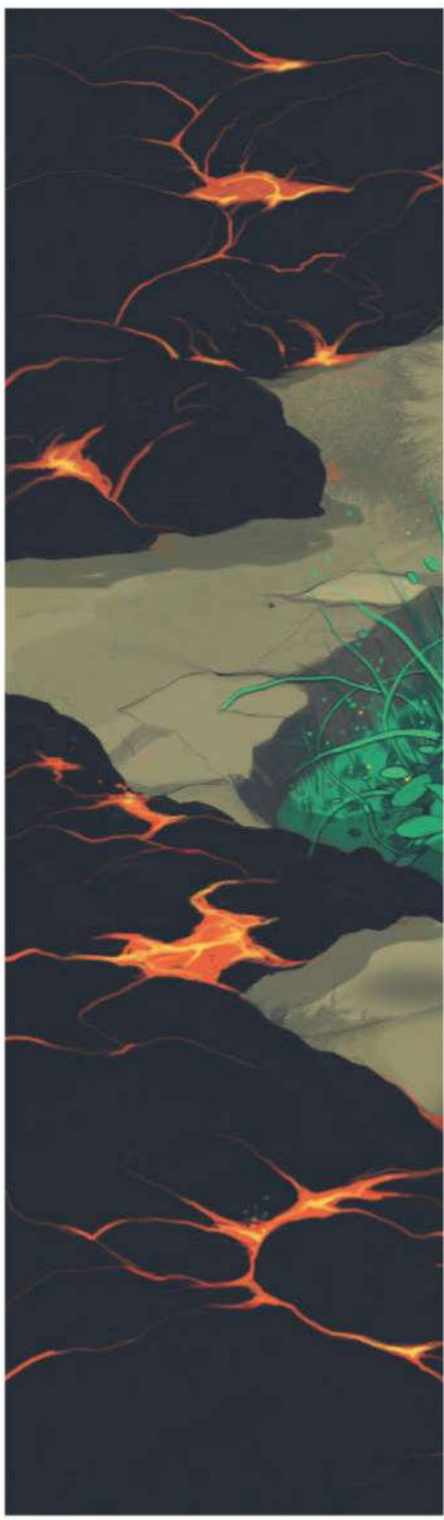
FOR WHAT COMES NEXT

Tenacious life

Surprising new fossil evidence undermines the idea that there was ever a mass extinction on land, finds **Colin Barras**



SIMON PRADES

THE end-Permian mass extinction was the deadliest event in Earth's history. Also called the Great Dying, it is thought to have nearly wiped out all life on Earth 252 million years ago. Yet, earlier this year, we learned of an ancient ecosystem at South Taodonggou, a geological site in what is now China, where plants and animals were thriving just 75,000 years later – a blink of the geological eye. You might call it an isolated miracle.

Surprisingly, palaeontologist Hendrik Nowak at the University of Nottingham, UK, doesn't see it that way. He points to fossil pollen from other sites that also suggests "little or only short-lived disruption" from the end-Permian event. In fact, Nowak argues that the impact was so minimal that – for plants, at least – there simply was no mass extinction then.

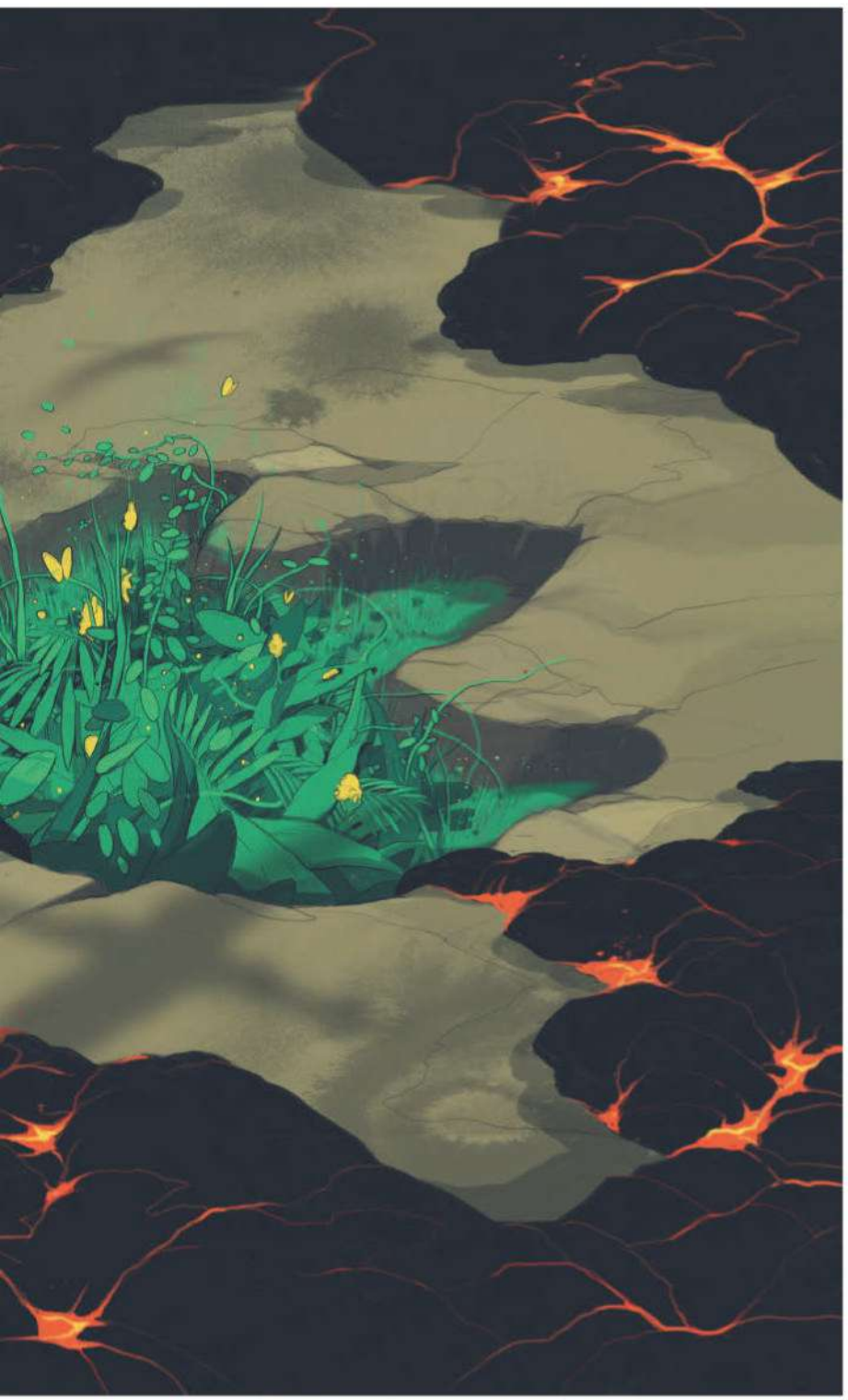
This conclusion is controversial. Nevertheless, studies on two other major groups of organisms – insects and four-limbed land animals – echo the findings in plants. The emerging picture means Nowak isn't the only palaeontologist questioning whether the impact of the end-Permian mass extinction was as colossal as we thought. Spencer Lucas at the New Mexico Museum of Natural History & Science goes even further – he suspects life on land has never experienced a mass extinction. "I think that you've got a better chance of beating a big extinction if you're on land than you do if you're in the sea," he says.

This revolutionary rethink could rewrite the history of life on Earth. It would upend the idea that the continents have witnessed five mass extinctions – and it even has implications for how we frame the current human-induced biodiversity crisis.

The most famous victims of a mass extinction are the dinosaurs that died out around 66 million years ago, but much of what we know about such events comes from studying marine life. Indeed, the idea that Earth has experienced five mass extinctions came from a 1982 analysis of the marine fossil record. Two palaeontologists, the late David Raup and Jack Sepkoski, tracked changes in marine biodiversity over the past half a billion years and noticed that the record was punctuated by five crashes. These were at the end of the Ordovician (445 million years ago), the late Devonian (372 million years ago), the end-Permian (252 million years ago), the end-Triassic (201 million years ago) and the end-Cretaceous periods, the latter being when most dinosaurs went extinct. These events came to be known as the big five.

Beyond the oceans

It remains beyond doubt that these mass extinctions devastated ocean life, but – dinosaurs notwithstanding – it wasn't initially clear that they had also rippled through ecosystems on land. Mike Benton at the University of Bristol, UK, recalls that textbooks from the late 1980s "stated quite categorically" that there was little evidence of an end-Permian mass extinction of four-limbed animals, or tetrapods, that lived on land. Modern tetrapods include all reptiles, amphibians, birds and mammals. That, says Benton, was largely down to a lack



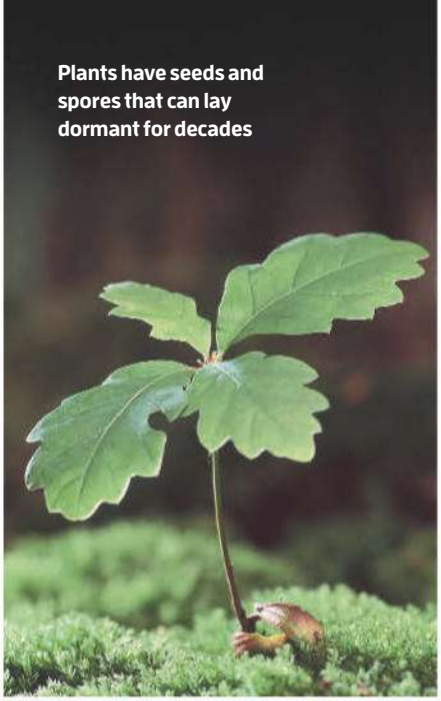
of data. It is relatively easy for a dead marine organism to be buried in mud and begin the fossilisation process, whereas land organisms are less likely to become fossils.

There are, however, a few sites that do capture a reasonably good fossil record of life on land during mass extinction events. Over the past 30 years, researchers have spent countless hours collecting and analysing tetrapod remains from such sites. A clear picture has emerged, says Benton: there were tetrapod mass extinctions on land to match those in the sea. This makes sense, given that the big five were driven primarily by a combination of rapid climate change and massive environmental upheaval, triggered by things like asteroid impacts and volcanic activity. "There are considerable feedbacks between the land and the oceans," says Benton. Runaway global warming, for instance, puts stress on both marine and terrestrial life. As such, he argues it is difficult to imagine a mass extinction affecting only one of the two realms.

So clear is this connection that many researchers now make it central to their understanding of these dramatic events. "Mass extinctions happen everywhere, all at once, on land and in the sea," says Paul Wignall at the University of Leeds, UK. Nevertheless, some have begun to express doubts and Lucas is prominent among them. In a 2017 paper, he examined the claim that there was an end-Permian mass extinction of land-based tetrapods. There were extinctions, he concluded, but fewer than 20 genera disappeared – hardly evidence of a catastrophic loss of diversity, given that there must have been many hundreds or even thousands of tetrapod genera at the time. "There was no big extinction of tetrapods on land at the end-Permian," he says.

Since then, Lucas has taken a critical look at the rest of the big five. In a review published in 2021, he concluded that land-based tetrapods were barely affected by any of them. "I think that there's a lot of hyperbole involved in this," he says. "It's a big deal that the non-avian dinosaurs go extinct at the end of the Cretaceous. That said, I don't think it's really a mass extinction." He points out that plenty of other large, land-living tetrapods, including the crocodilians, survived. And, of course, we now know that one group of dinosaurs – the birds – didn't go extinct, nor did the ›

"Insects are impressively well equipped to survive tough times"



Plants have seeds and spores that can lay dormant for decades

JUNIORS BILDARCHIV GMBH/ALAMY

KEVIN SCHAFER/NATUREPL.COM

Birds, such as the Indian peafowl, are evidence that not all dinosaurs became extinct

mammals. Lucas argues that tetrapods on land are in a better position to avoid extinction because air has a lower viscosity than water, which makes migrating to new regions following the deterioration of the local environment energetically less costly for land animals than for their marine counterparts.

Unsurprisingly, the claim that there has never been a mass extinction of land-based tetrapods has faced pushback. For instance, Benton maintains that the group did face a massive die-off at the end-Permian, with the disappearance of major branches including the sabre-toothed gorgonopsians – but that the extinction occurred over 1 million years. He says Lucas has "missed the bigger picture" by zooming in on the very end of that protracted extinction. Wignall is another critic. "I think it would be fair to say that Lucas's viewpoint is not mainstream," he says.

However, Lucas is not a lone voice in questioning the big five mass-extinction paradigm. Beyond the tussle over tetrapods, researchers who focus on other major groups of land-based organisms are coming to similar conclusions.

Take insects, of which there are millions of species today. In 2021, Sandra Schachat, now at the University of Hawai'i at Mānoa and Conrad Labandeira at the National Museum of Natural History in Washington DC assessed the fossil record of insects and concluded that the tiny animals seem never to have suffered a mass extinction. This doesn't mean they have had a crisis-free existence. Most notably, insect communities changed dramatically near the end-Permian, says Schachat. Important groups, including the dragonfly-like Palaeodictyoptera, vanished. Others, such as the Hemipteroidea – which includes the true bugs – rose to dominance. But crucially, she says, we have no idea how these changes came about because the insect fossil record is extremely patchy, with a gap of about 20 million years near the end-Permian. Over such a long period, insect communities can change gradually, but drastically, through evolution by natural selection alone. "When the fossil record is so incomplete that your best snapshots of a group of organisms come tens of millions of years apart, you're going to expect to see big changes, with or without a mass extinction," says Schachat.

Researchers including Wignall argue that it makes the most sense to tie the insect community changes near the end-Permian to a mass extinction. That is a possibility, says Schachat, but it ignores an important point: insect species are impressively well equipped to survive tough times. In their 2021 paper, she and Labandeira pointed out that insects occur in vast numbers and have short generation times. This means natural selection can proceed exceptionally quickly, helping insect species adapt to rapidly changing conditions. Moreover, faced with an acute crisis, individual insects can enter a period of dormancy called diapause until conditions improve.

Arguably, some marine invertebrates have similar features. But the fact that they live in the ocean may leave them more vulnerable to extinction, according to Schachat and Labandeira. Most notably, changes in atmospheric oxygen and carbon dioxide levels can trigger ocean stagnation, leading to the death of marine creatures through asphyxiation. Organisms on land don't face that problem. "We see tremendous changes in marine communities that correlate with drops in atmospheric oxygen, and then if we look at the record on land, we don't see anything like that," says Schachat.

The fossil record of land plants also fails to conform to the big five narrative. In 2013, Borja Cascales-Miñana, now at the University of Lille in France, and Christopher Cleal, now at the University of Bristol, took a close look at the record and concluded that plant mass extinctions are surprisingly rare. For instance, no family of vascular plants, a group that includes things like ferns and conifers, died out during the supposed fifth mass

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extinction at the end of the Cretaceous. In fact, they concluded, only one of the big five – the end-Permian – coincided with a mass extinction of plants. And as this year's study of the South Taodonggou fossils makes clear, even that is now questioned by some.

"It's pretty evident if you look at the fossil record from a broad perspective that something happened: the terrestrial flora changed quite a bit," says Nowak. For instance, forests dominated by the genus Glossopteris vanished in the end-Permian. "But can you call that a mass extinction?" In a 2019 study, Nowak and his colleagues argued that you can't. They concluded that this event affected some plants, including ferns, but had little impact on others. Conifers even appear to have increased in diversity. Cascales-Miñana and Cleal stand by their finding of an end-Permian plant mass extinction, pointing out that Nowak's team focused largely on pollen and spores, which are released in the billions by one tree, and so could create an impression of many plants even amid a large decline. "If you are counting spores, you are not counting plants," says Cascales-Miñana. But this controversy shouldn't detract from the broader message, which is that plants weren't badly affected by most of the big five mass extinctions. "I think that idea is pretty well accepted among palaeobotanists," says Cleal.

Again, the lack of mass extinctions among plants probably comes down to biology. They have several strategies for withstanding disaster. The most significant, says Cleal, is that they can survive for decades or even centuries as seeds and spores. "Imagine shooting all the elephants in the world: 10 years later, there are still no elephants," he says. "Now imagine cutting down all the oak trees in the world: 10 years later, there are the beginnings of new oak forests because the acorns germinated."

Like many insects, the yellow dung fly thrives on detritus

ANDY SANDS/NATUREPL.COM

A sixth extinction?

The fact that plants were largely unaffected by most – and potentially all – of the big five extinctions leads to an intriguing philosophical question, one that was first posed by Cascales-Miñana and Cleal in their 2013 paper. Should we label an event a "mass extinction" if it only affects a limited set of organisms and has little impact on other major groups? Lucas, for one, thinks we shouldn't. "How would you create a mass extinction on land?" he asks. "You would kick the floor out from under the food pyramid, take out the plants. But wait a second: the plants aren't going extinct at these events. Then how does the animal community collapse?"

The growing uncertainty about what counts as a mass extinction has implications for the way we think about the biodiversity crisis unfolding today because of human activities. Many researchers have begun labelling it Earth's sixth mass extinction, but, for life on land, it may arguably be the first. However, either label may not be warranted. For instance, Schachat and Labandeira argued in their 2021 paper that we need to see the disappearance of entire branches of the insect evolutionary tree to declare that a mass extinction of these animals has begun. They are undoubtedly experiencing catastrophic losses of abundance and biomass right now. "[But] there are no indications that we are anywhere near a crisis of this severity," the pair wrote.

It may seem unwise to question the sixth mass extinction idea – especially as it is framed as a rallying call to urgently conserve biodiversity, says John Wiens at the University of Arizona. Nevertheless, he thinks conservationists would benefit from abandoning this rhetoric. "Many people are now saying: we've got to stop the sixth mass extinction. But, actually, that is not an ambitious or even an urgent conservation goal," he says.

To understand why, we need to go back to basics. Surprisingly, there is no precise definition of the term "mass extinction", but there is a general consensus that these events see the loss of at least 75 per cent of species over the course of several thousand years to around 2 million years. Meanwhile, estimates indicate that over the past 500 years, less than 0.1 per cent of known species have become extinct. In a paper published earlier this year, Wiens and his colleague Kristen Saban at Harvard University point out that these figures suggest avoiding the sixth mass extinction will be a breeze.

"We could lose half the species on the planet over the next 3000 years and still say, 'Yeah, we did it! We prevented the sixth mass extinction,'" says Wiens. Targeting such an easily achievable goal risks doing more harm than good. If we really want to conserve biodiversity, we should aim to prevent human-induced extinctions rising to 0.2 per cent, not 75 per cent or even 50 per cent, he says.

No doubt, the debate about whether life on land has experienced five mass extinctions, one or even none will continue. Whatever palaeontologists conclude, that doesn't change the urgent need to address our current crisis, says Wiens. "It's popular right now to talk of a sixth mass extinction. But it's just the wrong way to think about it." ▮

Colin Barras is a freelance writer based in Ann Arbor, Michigan

"Corporations are the new disease vector"

Tracey Woodruff says that large companies now have more control over people's health than the individuals themselves. She tells Graham Lawton how research has revealed this – and explains how all of us can fight back

THE AISLES seem to go on forever as you push your shopping trolley towards the cereal section. You arrive, only to be met with an anxiety-inducing dilemma: do you buy the granola with low sugar or the one that is fortified with protein and vitamins? Or maybe the one with those delicious little chocolate chunks?

The supermarket can be mildly overwhelming, but at least there is no shortage of consumer choice. It seems that we are in control of the food we eat and the lifestyles we lead. We can make decisions that lead us towards better health, or we can take measured risks – after all, what would life be without a little chocolate now and again?

Health scientist Tracey Woodruff begs to differ. While a researcher at the US Environmental Protection Agency (EPA), she witnessed the tactics that corporations use to hide the harms caused by their products – and to skew evidence about their potential benefits. What's more, some of these products have contributed to a rising tide of toxic pollutants in our environment that is impossible for even the savviest consumer to avoid.

In February, Woodruff became the founding director at the University of California San Francisco's (USCF) Center to End Corporate Harm, which aims to reveal the methods that companies employ to distort science in the interests of profit. She told *New Scientist* about the growing health problems associated with contaminated environments, why corporations should be regarded as a disease vector, and what can be done to counter industry's harmful influence.

Graham Lawton: Let's start with the basics. What kinds of health problems are you interested in?
Tracey Woodruff: The global burden of disease has shifted since the 1990s. It used to be that the largest burden was from infectious diseases. That's decreased, which is a success. But what we're seeing now is an increase in the burden of chronic diseases – such as cancer, cardiovascular disease, diabetes and obesity – at a greater rate than communicable diseases have gone down.

This is a sudden shift, so we know it's not genetic. A key driver is a handful of industrial products: air pollution from fossil fuels, sugar and ultra-processed food, tobacco, chemicals and alcohol. These five are responsible for almost 30 per cent of the global burden of death, according to the Institute for Health Metrics and Evaluation at the University of Washington School of Medicine. That is huge.

What can be done about it?
If we as a public health community want to address the growing burden of chronic disease, we need to look at corporations as a disease vector. A communicable disease vector like a mosquito is a living organism that carries and transmits an infectious pathogen to another living organism via blood-sucking, for example. Corporations are the new disease vector because they transmit toxic exposures by manufacturing products or emitting contaminants that harm and kill people. We have to study the methods of these corporate drivers of disease if we want to prevent them.

What do we know about how these companies tend to operate?
One common method is hiding information. Corporations may make discoveries about the toxicity of their product and not release it to the public. For instance, my colleagues and I recently analysed corporate behaviour around PFAS, also called forever chemicals, which we know cause adverse health outcomes. We found that the chemical companies 3M and DuPont knew for decades that these chemicals were harmful, and yet they were using them and just dumping them into the water. It was and still is really tragic. (*Editor's note: There have been a number of lawsuits brought against DuPont and, separately, 3M, relating to PFAS chemicals, some of which are known to be toxic to humans. The companies have made* ›

NATALIE FOSS

payments to settle some of these cases but have not admitted liability.)

Corporations also try to undermine the scientific process. They fund research that is favourable to their products and create industry trade groups like the Tobacco Institute to conceal the direct corporate funding of research. There are many examples. In an illuminating case, revealed in 2005 by researchers at UCSF, R.J. Reynolds, Brown & Williamson and several other tobacco companies funded a scientist to be the lead author of a journal article casting doubt on proposed stricter safety limits on the pesticide phosphine, which the companies used to fumigate stored tobacco. The article was published in a journal of which the scientist was editor-in-chief.

Corporations may also skew findings when they come out, as they are selective in the way that they promote information. And, if the public starts to see that a product is causing health harms, the industry will cast doubt on the science.

REMKO DE WAAL/ANP/AFP VIA GETTY IMAGES

There's not a great deal people can do about their exposure to air pollution

How is it that corporations have such sprawling influence over the direction and outcomes of research?

In a world where it's challenging to get grants – and in the US, it could be getting harder because of the proposed cuts to research funding by the Trump administration – people are looking for other sources of funding. And then researchers don't want to speak out because they could lose their funding.

You have also said that some companies also rig the regulatory process. Tell us about how this works?

I saw this when I worked at the US EPA, where I advised on guidelines that are used to evaluate the carcinogenicity of different chemicals. The EPA is one of the few federal agencies that has the power to influence every industry in the US, so many corporations are very actively engaged in its activities. They have a financial stake in getting their products approved, and they have money to spend on making their interests known. It felt like every chemical had its own personal lobbyist.

At the EPA, there are advisory panels that peer review the science. But people who have financial conflicts of interest are included on these panels. Research has shown that even when conflicts are declared, it still can produce more bias from members and can then bias the findings. In some cases, corporations hire former EPA employees as consultants to provide advice about strategy.

How, in general, do you find out about what companies are doing behind the scenes?

Back in the 1990s, a UCSF professor, Stanton Glantz, received some internal documents from the tobacco industry, and he made the very wise decision to check all the documents into the library. Once they were in there, even though the tobacco industry tried to get them back and sued, they were protected under academic freedom. That was the beginning of the UCSF Industry Documents Library.

The value of the library is that you can read what the industry was saying in their own words, what they knew and when they knew it. There have been over a thousand research publications using the library to identify how they influenced the scientific and regulatory processes.

Since that time, there have been other collections added. So we have the sugar and pharmaceutical industries, we have a small collection on forever chemicals, we have asbestos-contaminated talcum powder, we have glyphosate – the active ingredient used in some weedkillers. Recently, we've acquired documents from the opioid industry.

How does the library obtain such documents? They were presumably never intended for public consumption.

We get them through various mechanisms. The original documents were sent from an anonymous whistleblower at the Brown & Williamson Tobacco Corporation. Some come from Freedom of Information Act requests. A lot of them have been collected through court cases against various companies, too. One of the things that comes out when you look at the documents is that the corporations act together – they share strategies, they collaborate, sometimes they hire the same lobbyists, sometimes they have the same front groups.

Does all this mean that we as individuals have less control over our health than we like to think?

Yes! It's not that people have no control over their health, but there are a lot of structural factors that make it difficult. A good example is the food system. When you go into the grocery store, ultra-processed food occupies a lot of space. There have been estimates that about 70 per cent of the foods in the store are ultra-processed, and it's continuously marketed to you. That makes it hard to avoid those products. Air pollution is another good example: if you live near polluting sources, you have little control

over the polluted air you breathe.

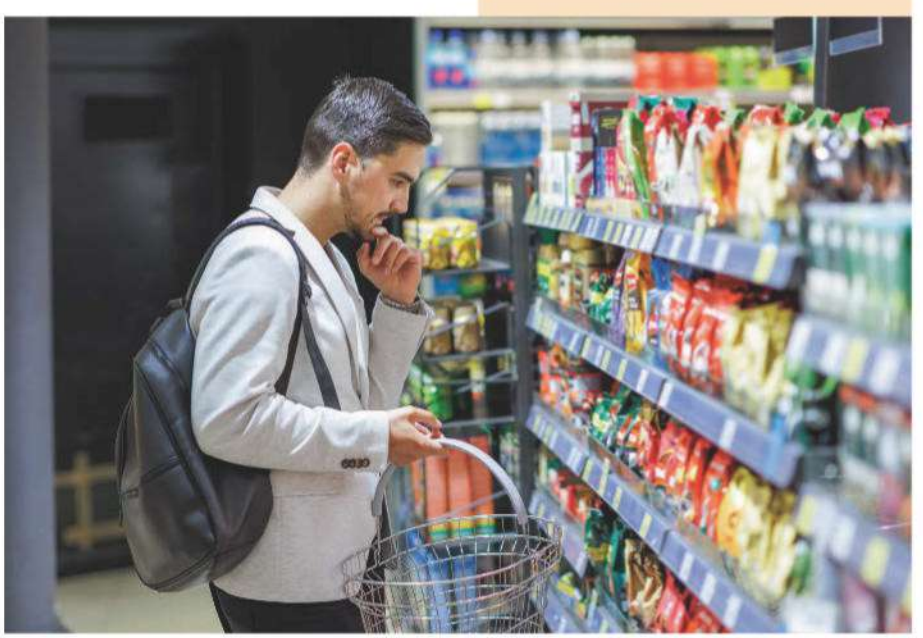
This idea goes against the grain of corporate messaging, which often suggests that we are responsible for our own health. One of the threads that came out from the tobacco papers is that industry lays blame on the individual: "It's your fault, you didn't exercise, you ate a bad diet, you smoked." The trouble is, that distracts from one of the more effective ways to solve the problem, which is government regulations.

It sounds like corporations have more control over our health than we do …
Yes, I would agree with that.

People who hear that might wonder: what can I do?
It's a two-pronged approach. First, you can take individual actions that will reduce your exposure to toxic chemicals, such as reducing the use of plastics and installing an air filter in your home. People can also send signals to the market, for example by not buying harmful products. Second, we also encourage people to be engaged civically, because we need government action to implement systematic changes. Register to vote, actually go and vote, and then tell your government officials what you want. You have to recognise that industry has a profit motive. They're responsible to their shareholders, not responsible for the public's health, so we have to force the issue.

> "We have to study the methods of these corporate drivers of disease if we want to prevent them"

The vast consumer choice we have can create the illusion of control over our health



REAL PEOPLE GROUP/GETTY IMAGES

One aim of the centre you direct is to find ways to counter industry's influence. What might those look like?
The first is to remove people who have financial conflicts of interest from all government review boards and committees. We know this can be done; the International Agency for Research on Carcinogens, which is a division of the World Health Organization that reviews the science on environmental factors' potential to cause cancer, put in place a policy to this effect in 2015.

It is also important when you're doing evaluations of scientific evidence that you identify and account for any financial conflicts of interest in the funding of studies. In that way, you can ensure that your evidence evaluation is more robust and less biased.

Finally, increasing government funding of science so that scientists don't have to be reliant on industry funding would help to reduce the influence of corporations.

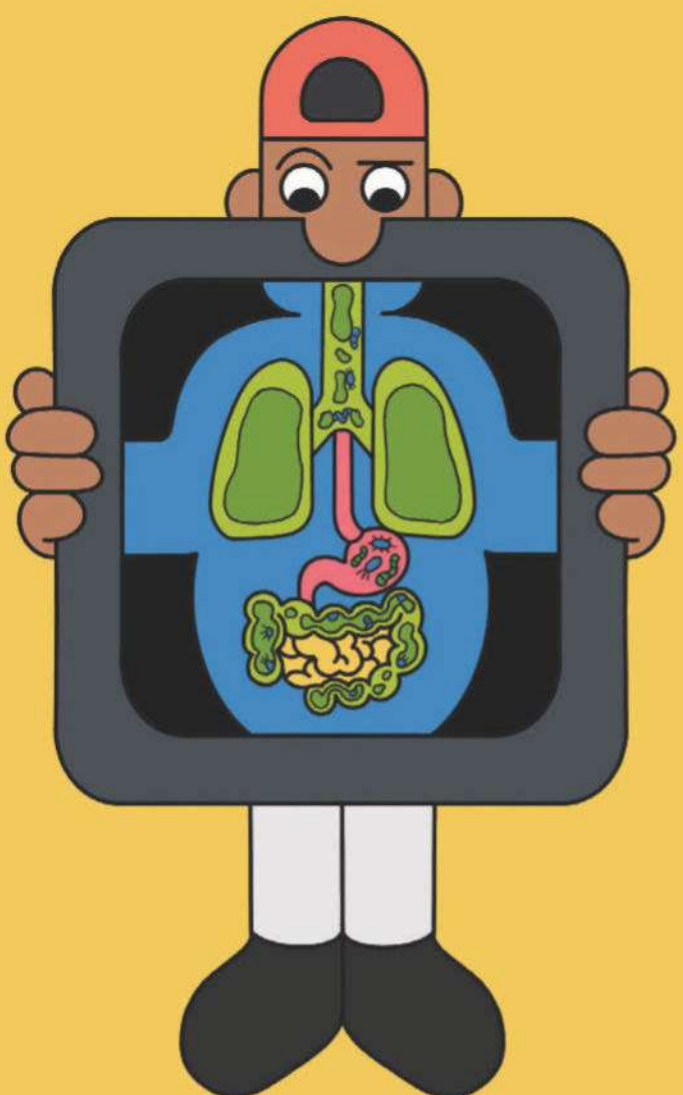
And are you expecting pushback against what you're doing?
Many of the members of the centre have had pushback on them individually, or on the work they're doing. One has a long history of working on how the tobacco industry influences science and policy, and early in her career the tobacco industry flat-out attacked her by sending letters to UCSF saying that she shouldn't be promoted. So we could expect some of that too.

You are swimming against the political tide.
Yes, but there's a silver lining in that there is a portion of the population that wants the government to do more in this area. I think there was a component of the 2024 US election that was about people's frustration with the government in addressing the growing burden of chronic disease. People are concerned and – I think rightfully – a little scared that their friends are sick and the government needs to do a better job of helping them. ▮

Graham Lawton is a staff writer at *New Scientist*

Marvellous mucus

Long overlooked in medicine, mucus is far more than a simple barrier, finds **Grace Wade**



TRAVIS CONSTANTINE

MOST of us would rather not dwell for too long on the subject of mucus. We know it is there, quietly lubricating our insides and presumably doing vital work. It is only when we have a cold that we give it any particular attention – and even then, it is an unpleasant nuisance, something to be wiped away as discretely as possible and chucked in the bin.

Yet new research is revealing just how marvellous mucus is. Of course, we have long known that it plays a key role in fending off disease, but it was mostly thought of as nothing more than a sticky physical barrier. We now know it is far more sophisticated: it is a substance that can morph, adapt and even change the behaviour of invading microbes. "We are actually now learning more and more that it is very dynamic," says biochemist David Thornton at the University of Manchester, UK. "It is not just an inert barrier."

These discoveries are prompting a dramatic rethink of the slimy stuff. Mucus is increasingly inspiring new medicines, such as experimental drugs that may one day replace antibiotics, while understanding where mucus goes wrong is leading to new treatments for conditions such as inflammatory bowel disease. As researchers continue to unravel its secrets, we may find that mucus holds the keys to improving our health and fighting off disease.

You might not know it, but you are oozing with mucus. It covers 200 times more surface area than skin, coating every one of our moist surfaces, inside and out, from our eyeballs and sinuses to our lungs and stomach. It even lines the inner ear. But despite being smothered in the stuff, we knew relatively little about mucus until the past two decades – and a lot of what we thought we knew turned out to be wrong.

But let's start at the beginning. Mucus is believed to have first evolved hundreds of millions of years ago in marine invertebrates, such as corals and jellyfish, as a protective barrier and digestion aid. It is now found across the entire animal kingdom and performs an array of functions, including lubricating surfaces, guarding cells from damage, clearing away debris and regulating immune responses. Yet for much of history, this gooey wonder – especially when there was too much of it – was seen more as a sign of illness rather than a fighter of it.

We now know that mucus is actually here to help, and it is uniquely suited to each surface it coats. While the stuff in our stomachs is thick and acidic, the goop in our nose, mouth and lungs is runnier and on the neutral side, making it easier to clear from airways. While its exact formulation varies throughout the body, it always contains a few key ingredients: about 90 to 95 per cent of it is water, large proteins known as mucins comprise up to 5 per cent, and the rest is a mix of electrolytes, fats and other proteins.

It is the mucins that are the real secret to the sauce. These molecules resemble fuzzy caterpillars, with hundreds of stringy sugars called glycans sprouting from their long protein backbones. The sugary offshoots attract and retain water, giving mucus its slippery, gel-like consistency. Once secreted, mucins cross-link with themselves and other compounds, creating a mesh-like configuration. The more mucins in mucus, the denser this network becomes, resulting in smaller gaps – or pores – in its structure.

Until about 15 years ago, it was widely assumed that pore size alone determined whether something could pass through mucus's sticky defences – larger entities, like bacteria, may be thwarted, while smaller substances, such as nutrients, could slip by.

Super slime

But then a series of findings began poking holes in the premise. In 2010, Katharina Ribbeck at the Massachusetts Institute of Technology and her colleagues measured how quickly microplastic beads with varying electrostatic charges moved through pig mucus. They found that beads with a slight negative charge passed through up to 10 times faster than those with strongly positive or negative charges. Mucus's acidity also influenced its permeability: plastic particles with a slight negative charge diffused twice as fast when mucus was neutral than when it was acidic. These findings helped lay the groundwork establishing that mucus is much more than a simple sieve.

"Mucus provides really two categories of protection," says Ribbeck: a physical barrier shielding the body from unwanted objects and molecules, and a chemical barrier, actively interacting with foreign materials. In that way, mucus is almost like a bouncer at an exclusive nightclub, deciding who gets through. Mucus also changes according to our needs: for example, human cervical mucus becomes ›

> This really is a kind of very well-engineered environment

thinner and more watery during ovulation, enabling sperm to penetrate it more easily. It might even respond to our body's internal clocks, according to unpublished research from Thornton and his colleagues. They found that the composition and thickness of mucus in the guts of mice shifts between day and night. "This really is a kind of very well-engineered environment," says Thornton.

Once it was clear that mucus could interact with foreign entities, Ribbeck began wondering what the implications of this were for the trillions of microbes we encounter. "Many of these critters are benign, but of course, there are also problematic pathogens in this mix," she says. "Over millions of years, mucus has, it seems, evolved to keep those pathogens in check. And the question was, how does it do so?"

The first clue came in 2012. Ribbeck and her colleagues were working with the bacterium *Pseudomonas aeruginosa*, which can cause difficult-to-treat infections throughout the body. Like many bacteria, the microbe only becomes dangerous when it clusters together into gooey, toxic matrices called biofilms. At the time, the prevailing belief was that although mucus kept these nasty bacteria from reaching underlying tissue, its sticky nature actually enabled the microbes to clump together more easily.

Yet when the researchers exposed the bacteria to a solution containing pig mucins, they found the opposite. "They didn't aggregate at all," says Ribbeck. "In fact, if anything, they stayed separate and were less able to cause harm." After 6 hours, only about 15 per cent of the bacteria in the mixture had begun forming biofilms, compared with more than 40 per cent of those in the mucus-free control.

Further experiments in 2019 revealed that mucins achieved this feat by reducing the activity of genes that allow *P. aeruginosa* to communicate, produce harmful substances and form biofilms. It was the mucins' sugar molecules – the glycans – that triggered these effects, albeit in a surprising way. The glycans don't kill the bacteria – instead, they are a food source. "It is like giving a kid a lollipop. They will calm down. Usually, they stop fighting," says Ribbeck. Treating the microbes to a glycan seems to tame them, rendering them less harmful, she says.

Ribbeck and her colleagues have since identified numerous glycans capable of managing problematic pathogens. For example, in 2022, they found glycans that can suppress a fungus responsible for yeast infections called *Candida albicans* and others that keep cholera-causing microbes at bay; in 2024, they found others than can protect against strep throat. "[Mucins] present dozens of different sugar molecules, and these sugar molecules all have different functions," says Ribbeck. "It is basically like a broad-spectrum microbial management library that is in action in our body."

From mucus to medicine

All this raises the thrilling possibility of taking inspiration from mucus to create new medicines. One strategy could be to use glycans themselves, or molecules mimicking them, as alternatives to antibiotics or immunotherapies. Ribbeck says that, in unpublished work, she and her team have already formulated one glycan-inspired molecule that can reduce the toxicity of *C. albicans*. The next step is making it into a medicine.

They are also hunting for glycans that could combat pathogens involved in traveller's diarrhoea, dental cavities and lung infections.

Cervical mucus becomes thinner during ovulation to allow sperm through

DR ISABELLE CARTIER/SCIENCE PHOTO LIBRARY

There might even be molecules that could boost the immune system or curb infections caused by microbes that are hard or impossible to manage with antibiotics. "I really think we can learn to manage not just unwanted, problematic pathogens, but also the immune system if it goes awry," says Ribbeck. She is now in the process of launching a company to bring these therapies to market.

Other experimental treatments inspired by mucus are further along the pipeline. For instance, Guangshuai Zhang at Shenyang Pharmaceutical University in China and his colleagues have developed an oral drug that may help strengthen the intestinal mucus barrier in people with inflammatory bowel disease. Though it hasn't been tested in humans, the treatment formed an artificial mucus layer in the intestines of mice with symptoms of the condition, shielding inflamed tissue from harmful bacteria and dampening inflammation.

But given how important mucins in particular seem to be in protecting against disease, researchers are now racing to identify their full range and catalogue exactly what they do, assembling a "mucinome" analogous to the genome.

Humans have at least 21 types of mucin, each with a unique structure and function giving it distinctive properties. Mucin MUC5B, for instance, interacts with hair-like structures in airways to propel mucus, along with the particles it traps, up and out of our lungs, while MUC2 is the major mucin in the gut, playing a key role in protecting the cells lining its surface – the epithelial barrier – from bacteria.

The mucinome is far richer than this though. It also includes what are called "mucin domains", which have the same fuzzy caterpillar appearance as mucins but are smaller, repeating pieces of a larger, non-mucin protein. Carolyn Bertozzi at Stanford University in California and her team are uncovering these structures in proteins throughout the body – in a 2022 study, they found that about 2 per cent of all proteins in the human body contain mucin domains, many of which we didn't know existed before. We are only just now learning what their functions are.

"Our interest in the mucinome is how it changes in disease settings and whether there are ways to intervene," says Bertozzi, explaining that deficient mucins or shifts in mucin levels could play a role in a wide variety

GEOFF CADDICK/AFP VIA GETTY IMAGES

Mucus helps to trap and remove particles from airways

> “It is becoming really obvious how important mucus is to our health

of conditions. In chronic obstructive pulmonary disease, for example, increased levels of another mucin, MUC5AC, in airways leads to an overproduction of mucus that clogs lungs and seals in pathogens. Mucolytics, drugs that break the bonds linking mucins together to thin it out, are used as a treatment. Other studies have shown that people with ulcerative colitis are deficient in MUC2; their mucous is thinner and less sticky, allowing pathogens to break through.

Changes in the mucinome might also be affecting conditions that seem unrelated to mucus. Recently, Bertozzi and her colleagues found that declines in mucin abundance may contribute to age-related cognitive decline.

In the brain, a layer of specialised cells that lines blood vessels – known as the blood-brain barrier – strictly regulates which substances in the bloodstream can cross over into brain tissue. “In young mice, those cells have a nice, thick, juicy mucin coating that we think is part of maintaining the blood-brain barrier,” says Bertozzi. “But in old mice, which notoriously have a leaky blood-brain barrier, we discovered that blood vessels have a very thinned out mucin layer.”

Using gene therapy, the researchers increased mucin production in these blood vessels, which in turn, improved cognitive performance in older mice. Bertozzi and her colleagues have since patented the therapy. While it hasn’t been tested in people, the researchers are hopeful it could slow or even reverse age-related cognitive decline.

So, knowing that mucus is deeply important to overall health, what can you do to keep your mucus in good shape? A healthy diet seems to support our mucus barriers, in the gut at least.

For example, a 2017 study found that when mice were deprived of dietary fibre, their gut bacteria resorted to consuming mucins as a nutrient source, eroding their mucus barrier. In 2018, Rebecca Carrier and her colleagues at Northeastern University in Boston and her colleagues showed that common food additives, known as emulsifiers, can alter the composition and integrity of mucus. One emulsifier, carboxymethylcellulose, decreased pore size and slowed the movement of bacteria through intestinal mucus from rats. Carrier’s research also found that larger particles struggled to get through intestinal mucus when it was exposed to a solution of partially digested fats. This suggests that fats can strengthen our intestinal mucus, potentially by joining different mucin molecules together, says Carrier.

Taken together, she says, “what this means is that essentially our mucus barrier is probably changing depending on what we are eating”.

Carrier reckons it is too soon to make any firm mucus-boosting dietary recommendations. But, says Bertozzi, “one way you can protect your gut mucinome is to make sure you eat enough plant-based material and give your microbiome what it really wants”. In other words, keeping your fibre intake up can help maintain your gut, and staying well-hydrated can keep mucus flowing effectively through your airways. That is perhaps the best we can do for now.

Mucus may not be the most glamorous subject of study. But the more we learn about this slimy unsung hero the more it seems it is worthy of our attention. “We are in a time where it is becoming really obvious how important mucus is to our health,” says Ribbeck. “And I get a kick out of something as common as mucus having its moment to shine.” ▮

Grace Wade is a reporter for *New Scientist*

The back pages

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***Almost* the last word**
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Tom Gauld for *New Scientist*
A cartoonist's take on the world p47

Feedback
Scandal hits the burgeoning sport of sperm racing p48

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

The science of exercise

Keeping it down

Exercise is one of the most effective ways to lower your blood pressure, but what is the best workout to do, asks **Grace Wade**

Grace Wade is a health reporter for *New Scientist* based in the US

I NEVER thought much about my blood pressure, but recently my doctor suggested I start monitoring it more closely due to some of the medications I take. While it is still well within the normal range, it has slowly crept up, making me wonder what I can do to keep it in check. After all, high blood pressure is one of the most common health problems, affecting an estimated 1.28 billion adults. Left unmanaged, it raises the risk of various conditions, such as heart attack and stroke.

Exercise is widely recognised as one of the most effective ways to lower blood pressure. Most public health organisations recommend 150 minutes of moderate-intensity aerobic activity a week, such as jogging or cycling, to help keep it in check. Yet many recent studies suggest this may not actually be the most effective approach.

One of the most convincing findings comes from a 2023 analysis of 270 randomised controlled trials, involving almost 16,000 adults. Each trial investigated the effects on blood pressure of an exercise regime lasting at least two weeks. The analysis showed that every type of workout – from aerobic activity to resistance training – significantly reduced blood pressure compared with control groups.

However, isometric exercises such as wall sits and hand grips, in which a muscle is tightened in a static position, reigned supreme. On average, they lowered systolic and diastolic blood pressure by 8.24 and 4 mmHg, respectively, an effect similar to blood pressure medication. A drop of this magnitude is associated with up to a 22 per cent lower risk of a major cardiovascular event, such as a heart attack or stroke, for at least a few years. Aerobic exercises had almost half the impact.

LEOPATRIZI/GETTY IMAGES

The difference is probably to do with how isometric exercises affect blood flow. Think of wall squats and planks: they involve holding muscles in a contracted position for a minute or two. Squeezing muscles for that long temporarily reduces blood flow to them. When they are then relaxed, vessels widen, allowing blood to rush back in. This lowers blood pressure for several hours, and the drop becomes sustained with repeated exercise.

What makes isometric workouts even more appealing is that they are relatively easy to fit into your routine. A 2023 study found that just 12 minutes of these exercises three times a week for 12 weeks was enough to significantly reduce blood pressure.

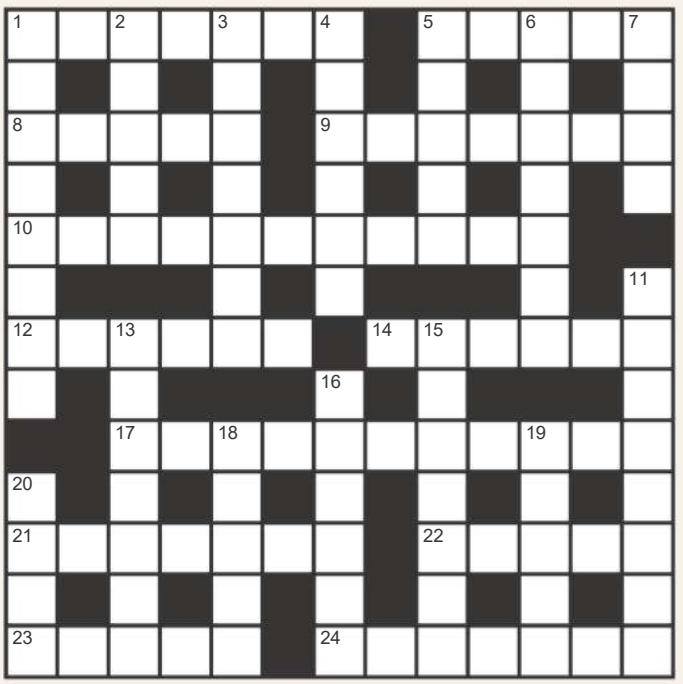
Now, I don't want to suggest we forget about other types of workout. Aerobic exercise and resistance training are still important for cardiovascular health and building muscle. But if you aren't seeing your blood pressure budge, it may be worth adding an isometric move or two to your workout routine. I, for one, will definitely start incorporating wall squats into my leg day. ▮

The science of exercise appears every five weeks

Next week
Dear David

These articles are posted each week at newscientist.com/maker

Cryptic crossword #163 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Worry about offer to buy hard material (7)
5 Gangs declared peace in ancient Rome (5)
8 Go get head of forensics and others at hospital (5)
9 In Paris, she can put back aircraft part (7)
10 Added disinfectant to cold, cracked hotel drain (11)
12 Circuits or routines (6)
14 Plan lifetime confidentiality contract (6)
17 Fun partner returned with fresh dilute medication (11)
21 Tim and Luis crafted spurs (7)
22 Limit on poultry selection (5)
23 Dump diamonds and yen (5)
24 Fixed tiller's support structure (7)

DOWN

1 No-charge coffee to which thespian's added enzyme supplement? (8)
2 Ranger finally fed large honey badger (5)
3 Come into empty inn with recluse, having lost millions (7)
4 Climate event misrepresented online (2,4)
5 Mary Jane clutches one piece of complicated looped embroidery (5)
6 Cancel a donation featuring green pottery (7)
7 Get rid of storage space (4)
11 Public spectacles summon colony members (8)
13 Musician's second-rate *Help!* (7)
15 Medium pain follows short joint affliction (7)
16 Sparkling silver fluff (6)
18 Trap nocturnal creature outside university (5)
19 Drive politician wearing upside-down garland (5)
20 Employed American publishing pro (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #305
set by Corryn Wetzel

1 What does CRISPR stand for?

2 What was the world's first programmable, electronic, digital computer?

3 Which colour of light has the longest wavelength on the visible spectrum?

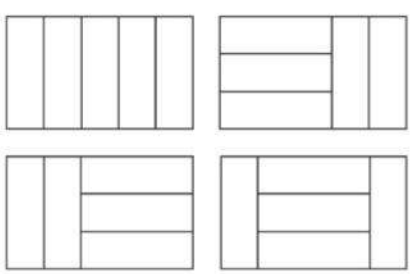
4 How many times does the average human heart beat in a day?

5 What year did the World Health Organization declare smallpox eradicated?

Answers on page 47

BrainTwister
set by Colin Beveridge
#76 Tromino trials

There are four ways to tile a 5 × 3 rectangle with five 3 × 1 "trominoes", as shown here.



If you have a 7 × 3 rectangle to tile with seven 3 × 1 trominoes, how many ways can the rectangle be tiled if exactly three are placed horizontally?

Other than three, what are the possible numbers of horizontal tiles in this rectangle?

In total, how many ways are there to tile the rectangle?

How many ways can you tile a 10 × 3 rectangle with trominoes?

Solution next week

Under pressure

Does car tyre pressure affect the radius of the wheel, or the speedometer or milometer (odometer) readings?

Ron Dippold
San Diego, California, US
Yes, it does! Though not as much as speedometer fudging by your car manufacturer. Your car can only measure rotations of the axle, with expectations of tyre circumference based on its standard tyres. The distance travelled is rotations multiplied by circumference, and then, of course, the speed is the distance travelled per hour. So everything depends on that assumed circumference.

Underinflated tyres bulge out: the air goes to the sides, exactly like you pushing down on the top of a balloon. This makes the distance from axle to ground less than expected, so the "loaded radius" is smaller. Overinflated tyres will bulge less under a load, so they have a larger loaded radius than expected. A 20 per cent pressure change in a relatively soft tyre results in about a 1.5 per cent change in loaded radius. If your soft tyre suggested 38 pounds per square inch (PSI) of pressure and you had 30.4 PSI, it would have a 1.5 per cent smaller loaded radius.

"When tyres are 20 per cent underinflated, your car would show 100 km travelled when you had travelled only 98.5 km"

Since circumference is $2\pi r$, where r is the radius, this directly translates to reading 100 kilometres per hour when you are actually doing 98.5 km/h. If you overinflated those soft tyres by 20 per cent to 45.6 PSI (which is unsafe, as 10 per cent over is about as far as you want to go), you would be doing 101.5 km/h when the speedometer is reading 100 km/h. This affects the milometer (odometer) in the same fashion. When tyres are 20 per cent underinflated, your car would show 100 km travelled when you had travelled only 98.5 km.

In reality, 20 per cent is fairly severe over or underinflation, and stiffer tyres have much less change – you would need a dangerous 30 per cent over or underinflation to get 1 per cent change in a stiff tyre. Furthermore, even a 1.5 per cent error is nothing compared with your speedometer being calibrated slightly higher by the manufacturer. By European Union law (which has been retained by the UK), the speedometer can never show lower than actual speed, but is allowed to show 10 per cent plus 4 km/h over. So you could be doing 50 km/h with the speedometer showing 59 km/h, and that would be legal, and this 10 per cent standard is typical. In practice, it's always calibrated slightly higher, so it never reads under. For instance, when my car reads 50 km/h, radar says it's doing 48 km/h – so my speedometer is calibrated 4 per cent over, which overwhelms any tyre inflation differences. Car manufacturers also like this because it makes your warranty expire 4 per cent sooner.

Greg Nuttgens
Porthcawl, Bridgend, UK
Yes, the tyre pressure does affect the radius of the wheel. In fact, this is how the warning system of low tyre pressure in modern cars works: a decrease in pressure results in a slightly smaller wheel radius, and this is detected by sensors that count the tyre revolutions. If the speed revolution of the car's tyres doesn't match, a warning light comes on.

John Davies
Lancaster, UK
A tyre isn't a doughnut-shaped balloon! It is carefully constructed, with a "skeleton" of steel and polymer wires under the rubber "flesh" so that, at the correct inflation pressure, it presents a flat surface to the road, despite that pressure being more than twice the atmospheric pressure. But that skeleton isn't rigid, nor should it be! An overinflated tyre will bulge in the centre of the tread, as it tries to assume a doughnut shape, wearing more of this area.

This effect is small on the rolling circumference of the tyre, but it will increase so that the wheel will rotate fewer times for the same distance travelled, and the apparent speed registered by the speedometer will fall. But don't rely on this to excuse a speeding fine!

SHUTTERSTOCK/OLHAROHULYA

Do non-pollinating animals like dogs also find flowers beautiful, like we do?

This week's new questions

Floral attraction **Why do humans like flowers? And do other non-pollinating animals also find flowers appealing, even when there is no obvious benefit?** ***Miles Drake****, London, UK*

Quick dry **What's the best way to hold my hands under a hot air blower to dry them efficiently: flat or cupped? Or something else?** ***Adrian Moore****, Maidenhead, Berkshire, UK*

Hot meal

Can you reheat food without additionally cooking it? Is there a threshold temperature that begins the re-cooking process?

Matthew Stevens
Sydney, Australia
Cooking is the application of heat to food. So, applying heat to cold leftovers will cook them further. One very important process in cooking is a chemical reaction known as the Maillard reaction, in which sugars become linked with proteins. This results in the mouth-watering scents of cooked foods, particularly meats. Although heat hastens the reaction, it continues in the fridge, albeit slowly. This explains why

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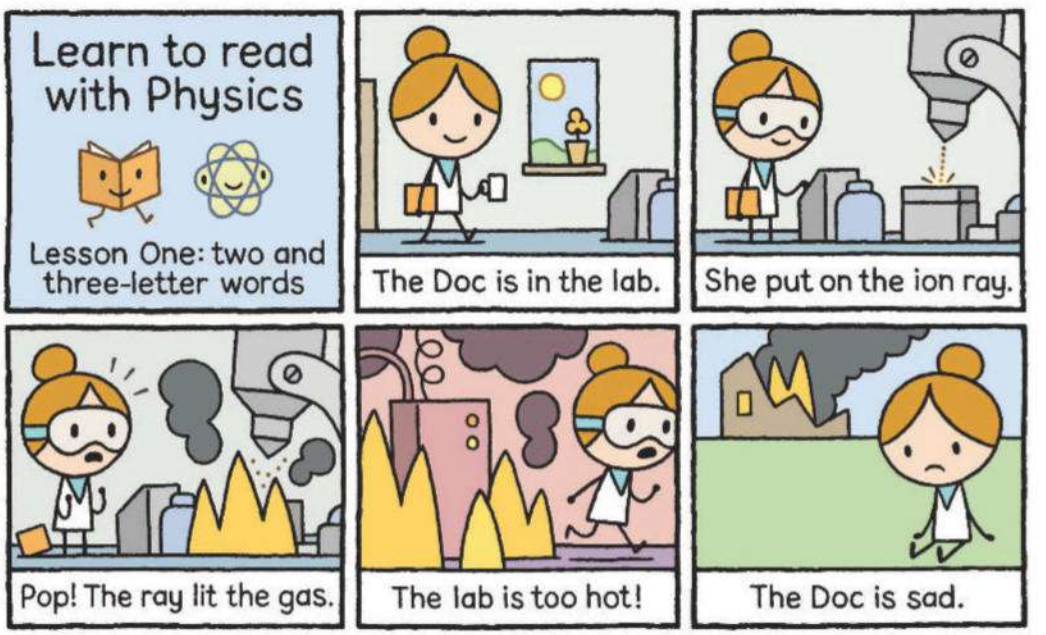
Tom Gauld
for New Scientist


Learn to read with Physics
Lesson One: two and three-letter words
The Doc is in the lab.
She put on the ion ray.
Pop! The ray lit the gas.
The lab is too hot!
The Doc is sad.

many foods taste even better the next day after a night in the fridge. In short, any amount of added heat will cook food.

Mike Follows
Sutton Coldfield, West Midlands, UK

Reheating food without re-cooking it is a delicate balance that requires care to avoid the risk of food poisoning. Reheating can unintentionally alter the texture, flavour or appearance of food, making it less appetising. It can also cause dryness or lead to the degradation of certain nutrients, such as vitamin C.

Cooking involves structural and chemical changes in food that are triggered at specific temperature thresholds. For example, proteins in eggs and meat begin to denature (i.e. cook) between 49°C and 71°C (120°F to 160°F) while starch gelatinisation in foods such as rice and pasta occurs between 60°C and 82°C (140°F to 180°F).

Ideally, reheating should restore food to a desirable eating temperature without causing further significant chemical changes. To achieve this, the process needs to be done quickly and evenly, to avoid partial heating or cold spots where bacteria might survive.

"*Sous vide* (French for 'under vacuum') is arguably the most effective method for reheating food without overcooking"

In most cases, food should be reheated thoroughly to 74°C (165°F), as recommended by the US Department of Agriculture, in order to kill harmful microbes and reduce the risk of foodborne illness. In such cases, some degree of re-cooking is inevitable. The temperature range between 4°C and 60°C (39°F to 140°F) is considered optimal for the rapid growth of bacteria, so it is important to minimise the time food spends in this so-called danger zone. However, if food intended for reheating has been cooled rapidly and refrigerated within 2 hours of initial cooking, it may be worth reheating it only to between 49°C and 60°C. This can help reduce the extent of additional cooking while still bringing the food to a safe and palatable temperature. For foods with a liquid or semi-liquid consistency, stirring during reheating helps to distribute heat evenly and eliminate cold spots. Using a food thermometer can confirm that the desired temperature has been reached.

Sous vide (French for "under vacuum") is arguably the most effective method for reheating food. It involves placing the food in a vacuum-sealed bag and immersing it in a precisely controlled water bath using a device known as an immersion circulator. This method allows for accurate temperature control and even reheating, significantly reducing the risk of overcooking or bacterial growth when carried out correctly. To prevent bacterial growth, food should be reheated only once. ▮

Answers

Quick quiz #305 *Answers*

1 Clustered regularly interspaced short palindromic repeats
2 Colossus
3 Red
4 100,000
5 1980

Quick crossword #184 *Answers*

ACROSS 1 Applet, **5** Bursitis, **9** Platypus, **10** Covert, **11** Tropopause, **12** Ruga, **13** Amaranth, **16** Shield, **17** Poison, **19** Coronary, **21** Crab, **22** Nerve agent, **25** Skylab, **26** Idiotype, **27** Crosstie, **28** Muscle

DOWN 2 Polar, **3** Lit up, **4** Topspin, **5** Bismuth, **6** Rickets, **7** Inversion, **8** Irregular, **14** *Moonraker*, **15** Rust belts, **18** Nanobot, **19** Carbide, **20** Rhenium, **23** Gates, **24** Nopal

#75 Letters and numbers *Solution*

If TWO = 2, then T = 1 and W = 1. If THREE = 3, then also H = 1 and R = 1. If FOUR = 4, then F+R = 4 and thus F = 3. If FIVE = 5, then F+V = 5 and thus V = 2. If SIX = 6, then S+X = 6, but we can't deduce either S or X yet. If SEVEN = 7, then S+V+N = 7 and thus S = 4, and, returning to SIX, X = 2. If EIGHT = 8, then G+H+T = 8 and thus G = 6. Then NINE can't equal 9 as N = 1 and thus NINE = 2.

If ELEVEN = 11, then L+V+N = 11 and thus L = 8. Then TWELVE = 12, so it is self-describing. If TWENTY = 20, then T+W+N+T+Y = 20 and thus Y = 16.

All other numbers less than 20 aren't self-describing.

Ready, set...

Athletics enthusiasts, here is a new competition for you to ogle: Sperm Racing.

You may have read that male fertility is declining, and that decreased sperm motility (speed of travel) is apparently a factor. To draw attention to this problem, the teenage founders of Sperm Racing decided to turn it into a sport. Or, to quote them: "We're building the first-ever racetrack for sperm. Two competitors. Two samples. One microscopic finish line."

Their website says they have created "a microscopic racetrack that mimics the reproductive system", and that "high-resolution cameras" will "track every microscopic move". They promise that "it's all live-streamed" (we assume that choice of phrase was deliberate) and that the winner will be "the sperm that crosses the finish line first, verified by advanced imaging".

The first race, on 25 April, pitted the sperm of donors from two Californian universities against each other. Readers might wonder why Feedback is so late to this story. For once, it isn't down to our usual tardiness about spotting news items. It's because there was a twist in the tale after the event.

Unfortunately for the organisers, a journalist went along: River Page, a reporter at *The Free Press*. In an exposé, he explained: "The winners were known in advance. And the 'race' was computer-generated."

The problem is that microscopes don't work like that. If you have a track long enough for sperm to swim competitively, there is no way to install a camera that tracks them. For films, a cameraperson can follow Tom Cruise as he runs along the roof of a moving train. But it's hard to keep a microscope focused even when the cells are virtually stationary.

The creators apparently ran a real race in a private room, and in order to "show" the sperm racing down the track for the benefit of a paying audience, they resorted to computer-generated imagery.

That led Feedback to think it unlikely that a second round of sperm racing would ever take place. Then we remembered that millions of people really love "sports entertainment" like wrestling, despite it being entirely fake, and also that the football results are largely determined by which team is owned by the neediest billionaire. So, sperm racing might indeed be the next big thing.

Twisteddoodles *for New Scientist*

MUM! TELL HIM TO STOP POKING ME!
HE STARTED IT !!
SCIENTISTS BELIEVE THE FIRST TETRAPODS MAY HAVE LEFT THE WATER IN SEARCH OF FIVE MINUTES' PEACE.
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Watery food

Feedback is a food connoisseur, in the sense that we have read about a lot of fad diets. Cut out all carbs! Just eat red meat, salt and water! Eat only raw foods! There is also such a thing as "air protein", but this just means "microbes that feed off carbon dioxide".

Just when we thought there were no new horizons to explore, we discovered "water-based cooking". Given living organisms are about 60 per cent water, our first thought was this might be another term for "cooking". But then we found headlines like: "Food fad or science – or both? Why cooking with water may help slow ageing" and "What is water-based cooking – and why it's better for you". It was time to go deeper.

Essentially, water-based cooking means you cook foods in water as much as possible, rather than oils. Boil, braise or steam; don't fry or roast. This reduces the quantity of advanced glycation end products (AGEs), found in the browned crispy bits on, say, a fried steak, which are linked to health issues. Therefore, say water-based cooks, we should avoid eating them.

The major driver of this is one Michelle Davenport: "a UCSF- and NYU-trained nutrition scientist, dietitian and former founder of a digital children's food company", who "teaches over 194K people on Instagram how to take control of their metabolic health through water-based cooking methods, inspired by her family recipes".

Hence a TikTok post that reads: "pov you started water-based cooking and now your skin is clear, your stomach is thriving and you recover from illness overnight".

Feedback feels like this might be overselling things just a tad, but that's wellness culture for you: if you are in anything other than perfect health, it's definitely the result of your own choices. Regardless, we can't help but sympathise with Elle on Bluesky, who says, simply: "It's soup. They're making soup."

Pizza surprise

We asked for examples of "no shit, Sherlock"-type scientific studies that go to enormous lengths to confirm things we might have guessed. The initial prompt was a study showing that SUVs are more likely than smaller cars to kill you if they hit you.

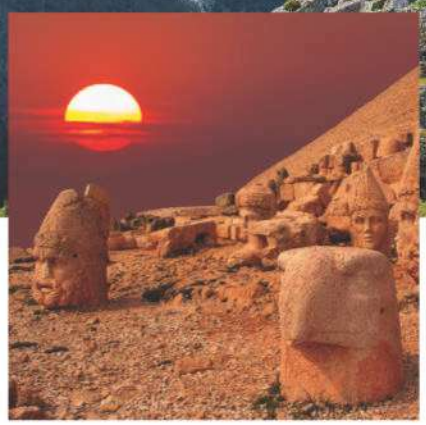
In response, reader Roger Erdem sent a selection of utterly unsurprising findings. Here's one. In *The Journal of Knee Surgery*, researchers led by Steven DeFroda published that "National Football League players have higher rates of knee extensor mechanism tears during short and normal rest weeks versus long rest weeks". Or, as the press release put it, "NFL players more likely to injure knee after shorter rest period". Well, yes.

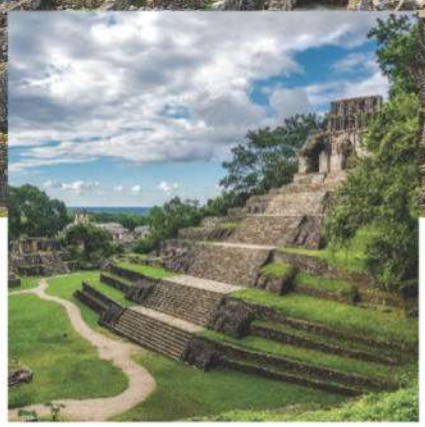
A second gem from Erdem concerned a study in *Nutrients* led by Katsumi Iizuka. This had the thoroughly enticing title, "The meal type rather than the meal sequence affects the meal duration, number of chews, and chewing tempo".

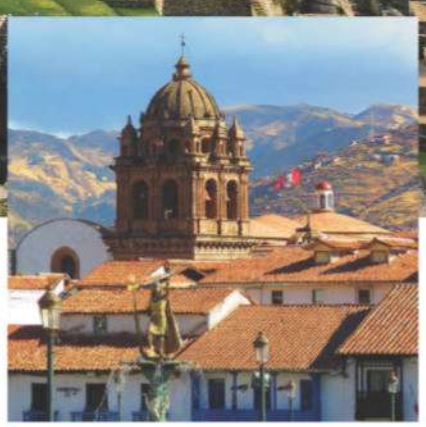
The study asks whether certain types of foods get eaten faster, contributing to obesity. Or, as a news story in *MedicalXpress* put it: "Study shows pizza is eaten faster than chopstick-based meals". It turns out fiddly tasks really do take longer.

Discovery Tours
NewScientist

Uncover the mysteries of ancient civilisations







Human origins: Neolithic and Bronze Age Turkey

10 and 24 September 2025
12 days

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- Enjoy the vibrant cities of Istanbul and Ankara, where rich history and modern culture seamlessly blend

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- Discover the vast archaeological site of Tikal in Guatemala, home to over 3000 buildings
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THE RAILMASTER

Minimalist design meets complex mechanics. This has been the story of the OMEGA Railmaster since 1957, when it was first designed as an anti-magnetic timepiece for workers on the railways. Those same enduring qualities are still evident today, yet the latest 38 mm model has taken its own unique direction with a new gradient dial in grey. An easy-to-read display is achieved through large Super-LumiNova hour markers, while the essential magnetic resistance is maintained through a modern Co-Axial Master Chronometer calibre.

Ω
OMEGA